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ON THE APPLICATION OF SCIENCE AND TECHNOLOGY
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Agenda Item: A.4.2.4

United Kingdom

THE EFFICIENT USE OF FUELS IN THE UNITED KINGDOM

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Papers have been contributed to the United Nations Conference on the Application of Science and Technology for the Benefit of the Less Developed Areas as working papers for that Conference. They are published as presented by the contributors, and the contents and the views expressed are those of the contributors. (See notes overleaf.)

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THE EFFICIENT USE OF FUELS IN THE UNITED KINGDOM

by

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1. In the last decade there has been, in general, a decline in the consumption of raw coal and an increase in the consumption of electricity and oil in all the main sectors considered in this paper. The use of electricity for road transport has, however, declined and the use of coke in domestic premises increased.(1) The changes in consumption of fuel and power have been accompanied by an all-round improvement in the efficiency with which they are used.

General Measures to Promote the Efficient Use of Fuel

2. During the inter war period 1919-1938 there was no very great incentive for the development of fuel efficiency measures in the United Kingdom because coal was both cheap and plentiful.

3. A body of professional engineers known as the Institution of Fuel Economy Engineers was already in existence in the early part of this period. This body merged in 1927 with the Institution of Fuel Technology to form the Institute of Fuel which has continued to have fuel efficiency as one of its main objectives.

4. From 1939 onwards, the Government actively encouraged interest in the subject. In 1941 a Fuel Efficiency Committee (F.E.C.), was set up to deal with all aspects of industrial and domestic fuel efficiency. Regional Committees were appointed and they received considerable

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(1) Ministry of Power, Statistical Digest, 1961, Table 8. Her Majesty's Stationery Office, London.

voluntary assistance from industrialists, engineers, scientists and others, and excellent collaboration from such organisations as the Federation of British Industries, Trade Associations, the Trades Union Congress and Regional Boards for Industry.

Industrial

5. An important step taken by the F.E.C. was to initiate the construction of heat balances at factories, by means of which the energy actually used could be compared with the theoretical energy required. This was followed by the introduction of mobile testing units which provided valuable quantitative advice to any firms on payment of a nominal fee. Experience showed that in average cases fuel savings of some 20 per cent could be obtained by implementing the recommendations made following surveys made by these testing units.

6. The importance of education and publicity in fuel efficiency matters was not overlooked. Two text books "The Efficient Use of Fuel" and "The Efficient Use of Steam"(2) were compiled under the auspices of the F.E.C. and published, together with over 50 Fuel Efficiency Bulletins and a number of instruction manuals. Educational courses were also developed and examinations in Boiler House Practice, Combustion Engineering, Instrument Maintenance, Heating and Ventilating and Fuel Technology were started.

7. National Industrial Fuel Efficiency Service. In 1953, it was decided to set up an independent non-profit making organisation to take over and expand industrial aspects of the work previously undertaken by the Government. Financed initially by the nationalised coal, gas and electricity industries, the National Industrial Fuel Efficiency Service was formed under the auspices of the British Productivity Council. This patronage was considered appropriate because the Council is representative of industry as a whole, it is independent of Government control, and fuel efficiency can make an important contribution to National Productivity. The sponsorship of N.I.F.E.S. has since been extended to include some of the oil companies.

8. The N.I.F.E.S. commenced operation in May 1954. The professional and technical engineering staff now numbers 184. Since its formation nearly 11,600 contracts have been undertaken and over 169,000 engineer-days service provided to clients. Over this period it is estimated that the total fuel savings due to N.I.F.E.S. activities amount to more than 13 million tons of fuel. The organisation has also trained over 6,000 boiler operators, and has produced a New Stokers' Manuel of which over 26,000 copies have been sold. In the last financial year the earnings of the organisation from chargeable services amounted to 88 per cent of their costs.(3)

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(2) Her Majesty's Stationery Office, London

(3) National Industrial Fuel Efficiency Service, Progress Report No.8 p.5., (1962).

9. Other Advisory Services. In addition to the foregoing, technical advisory services to fuel consumers are also provided free of cost by the coal, gas and electricity industries, the major oil companies and fuel distributors.

Domestic

10. From 1940 to 1951 domestic fuel efficiency was also mainly the concern of the then Ministry of Fuel and Power (now Ministry of Power). In 1951 some aspects of the solid fuel work were transferred to the Coal Utilization Council, which is a body representative of coal producers and distributors, and appliance manufacturers and distributors. The objective of the Council is to promote the efficient use of solid fuel in the home (a) by encouraging the coal and appliance trades to give a high standard of information, advice and service to the consumers, (b) by providing training facilities to enable the staffs of these trades to sell and service their goods to the best advantage and (c) by advertising the services available to the public, publicising the advantages of solid fuel and assisting the coal and appliance trades in providing their own publicity.

Legislative or Financial Measures to Assist Fuel Efficiency

11. Government Loan Scheme. In 1952 a Government Loan Scheme was instituted to promote efficiency amon small and medium sized industrial establishments. Money was loaned to finance most types of fuel efficiency measures in existing factories on condition that these resulted in substantial fuel saving and were such that in the absence of the Scheme they would not have been undertaken. Between 1952 and 1959 when the Scheme was terminated, the Government had lent about £5 million to assist about 1,100 schemes in the expectation of saving 360,000 tons of coal or its equivalent per annum.

12. Tax Allowances. From 1956 to 1959 a special taxation concession, known as the Investment Allowance, was retained as an additional incentive in respect of capital expenditure incurred on industrial fuel saving measures.

13. Clean Air Act. As the culmination of much public discussion on the evils of atmospheric pollution the Clean Air Act was passed in Parliament in 1956. Its effect on industrial fuel efficiency is likely to be beneficial since it requires plant to operate smokelessly. The Act is also affecting the pattern of fuel usage in domestic premises.

14. Insulation. In 1957 Parliament adopted legislation requiring a minimum standard of insulation for all new factory buildings erected after 1st January 1959.

Efficient Use of Fuels in Industrial Installations

15. Investigations carried out in the highly industrialised United Kingdom in the early post-war years provided conclusive evidence that

fuel consumption in existing factories could be reduced on average by some 20 per cent. Even now after many years of fuel efficiency crusading, savings of the same order are frequently found to be potentially realisable. This position is not likely to be any better in countries less highly industrialised.

16. Experience has clearly demonstrated two facts. Firstly, that the average level of plant operation is far lower than it should be and secondly, that installation of new plant will not necessarily improve efficiency unless the operator is properly trained in its use, and the plant is well maintained.

17. Whilst a qualitative assessment of the performance of existing industrial plant can often be made by visual observation, an engineer, no matter how experienced, cannot properly assess a boiler efficiency, discuss a furnace performance, or improve the performance of any heat using plant without measurement. One of the first steps towards improving fuel efficiency is therefore instrumentation to an acceptable standard. This has to be followed by the better training of operatives and better supervision of operation and maintenance by those responsible for boilers, industrial furnaces and process plant.

18. If the fuel costs of the factory are to be reduced to a minimum, steam, air, gas and water flow meters, temperature recorders etc., need to be installed to obtain continuous records of process requirements. It is found that a far more rigid control of operation and a higher degree of efficiency result from the increased use of instruments. Temperature, humidity, flow, etc., can all be controlled far more accurately with the aid of instruments than by rule-of-thumb methods, and once an operative has been taught the operation and function of instruments and controllers, he gains confidence in them and is able to devote more time to proper supervision of the plant.

The Technique for Improving Efficiency

19. With adequate instrumentation every factory can measure the quantities of fuel heat and power which it uses to manufacture a given number of units of standard quality product with the minimum of reprocessing or rejects. An endeavour should be made to break down the overall quantities into the individual process unit requirements. Such figures having been obtained, a heat balance can be prepared for the existing factory conditions. This will show the specific fuel and power consumption per unit of product for the factory as a whole, and the specific consumption of unit processes. If only the chief users of heat are considered, the most fruitful sources of savings (all the subsidiary heating requirements) may well be overlooked, even though they may take more heat in the aggregate.

20. The next step in determining the scope for improvement in fuel and power utilisation is to calculate as accurately as possible the theoretical heat and power requirement of each process and a "theoretical" heat balance can then be drawn up and compared stage by stage with the existing heat balance. This comparison will give an indication of the scope for

the better utilisation of heat and power and lead on to setting up a "target" for the process as a whole.

21. The establishment of a "target" must be a two-stage operation. In the first stage it is essential that each unit of plant should be made as efficient as possible. The second stage is to find the best inter-relationship of the individual units, so that the heat rejected by one may be used as the source of heat for another.

22. In the first stage, two fundamental questions must be answered: (i) can the escape of heat be prevented? and (ii) can the work to be done be reduced?

23. Consideration of these questions, and the subsequent carrying out of improvements, will give those responsible a true picture of what is going on in the factory and will make the operatives "fuel conscious".

24. The second stage of the operation focuses attention on the amount and grade of heat required by each process and rejected by each process. If the heat required or rejected cannot be metered it must be calculated from knowledge of the plant and the process being carried out. Wherever low grade heat is available, it is necessary to ascertain that full use can be made of it before attempting recovery. It may be necessary in order to recover such heat to instal waste heat boilers, air heaters, economisers or heat exchangers, water treatment plant and water storage tanks. Industrial furnaces may require recuperators, regenerators or some other form of heat exchanger and it may be necessary to prepare schemes for the utilisation of the heat recovered in some process plant remote from the furnace itself. Allowance must be made for any properties of the medium carrying the rejected heat (e.g. tendency to cause corrosion, abrasion or fouling) which may make heat recovery plant costly or uneconomical. These factors having been considered, it is possible to obtain a target for the minimum amount of fuel, heat or power which it is economic to employ for a unit of product and against which operating practice can be measured.

25. It will be clear that in many complex cases this type of work can only be carried out by a qualified specialist with a long experience behind him of the problems involved. Experience shows that 70 percent of the recommendations made arising from such surveys can be carried out with little capital expenditure.

Combined Heat and Power Generation

26. Industries fall into three categories: (i) large steam users whose steam demand is always so great that it is potentially possible to generate simultaneously more than sufficient power for their needs, (ii) those whose power and steam requirements are normally balanced and (iii) those whose power requirements are greater than could be met by back-pressure generating plant.

27. Factories in the first and second categories tend to become upgraded to the second and third. In general the more efficient a factory becomes

the sooner does it pass into the third category, because every economy in steam used or heat conserved in the factory processes reduces the amount of steam available for power generation. Most technical improvements, particularly of a labour saving character, reduce the factory heat demand and increase the power demand.

28. A large factory in category (i) or (ii) can generate power with a consumption of only 40 per cent of the coal used by a modern condensing power plant, by first passing the steam on its way to the heating process through an engine or turbine. Even a modest engine in a small factory need only use about 66 per cent of the coal burnt per unit generated by a condensing power plant.

29. Factories in category (iii) can either purchase their excess power from the public supply or generate their own by condensing part of their steam. There are many old-established factories in this category, generating their own power as a matter of custom but unless these factories are using the exhaust steam from their engines or turbines, at least in part for process work, they may be using, to take extreme cases, two or three times as much coal as the large condensing power plant of the public supply.

30. The official statistics for the U.K.[4] show that, discounting power produced by nuclear means, the total power generated by industry is now almost exactly what it was 10 years ago, about 11,000 million kWh, although a peak figure of 12,400 million kWh was reached in 1955.

31. The only detailed survey of "Steam and Power Usage"[5] in the U.K. was carried out in 1952-3 and suggested that there was scope, by installation of back-pressure generating sets, for saving some million tons of coal per annum.

32. Whilst the potential savings may appear attractive, thought has to be given to the varying conditions of specific industries and individual concerns, the cost of the necessary equipment, the prices of available fuels, and the necessity to discuss tariffs for the alternative supply of power from the national grid. When all these factors and others are taken into account, the advantages of combined heat and power generation are often marginal in many industries.

The Efficient Use of Fuels in Domestic Consumption

33. Nearly 30 per cent of the total consumption of all fuels is used in one form or another for domestic purposes. The chief changes which have occurred in the consumption of individual fuels in the domestic sector in

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(4) Ministry of Power, London, Statistical Digest 1961, Table 66

(5) Ministry of Power, London, Statistical Digest 1953, Tables 5-26
Her Majesty's Stationery Office, London

the last decade are a reduction in the consumption of raw coal from 58 per cent of the total to 46 per cent, an increase in the consumption of electricity from 18 per cent to 32 per cent, and an increase in the use of all fuels of 11 per cent. In the same period, the number of dwellings has increased approximately from 14.2 million to 16.7 million, or by 17½ per cent.

34. Liquid fuel plays only a small, but growing, part in domestic heating. A certain amount of oil is used for central heating and paraffin for individual room heaters which are also frequently used to provide supplementary and occasional heating in halls, passages, bathrooms etc.

35. Most dwellings in the United Kingdom are heated by individual room heaters. There is, however, a trend towards central heating, which is influenced by a number of factors such as the growing desire by many people for improved standards of heating, the increasing numbers of tall blocks of flats and the development of heating appliances which will provide economically full, or background, heating services.(6) Grouped building and district heating arrangements by means of thermal or thermal electric methods are installed, and experience has shown these are more likely to be economic when the building density is high. In new developments there may be special opportunities to combine the generation of electricity with district heating schemes. Many new blocks of flats are warmed by electric under-floor methods in which the heating cables are embedded in the floor structure. Off-peak electricity can be used with this and other forms of electrical thermal storage heating and the electricity supply authorities encourage its use by means of special off-peak tariffs.

36. Much emphasis has been placed on increasing the efficiency with which fuel is used in the home. Experimental houses have been erected to study the efficiency and economy of various combinations of space heating, water heating and cooking appliances and of differing standards of insulation.(7) This work has been supplemented by field tests and by surveys in various parts of the country of expenditure on heating and on tenants' reactions to differing methods of heating in houses and flats.(8) (9)

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(6) "Special Study of Domestic Heating in the United Kingdom" - Various Authors. The Institute of Fuel, London, 1956.

(7) Weston J.G., "Heating Research in Occupied Houses", J.Instn.Heat, Vent.Engrs., 19, (189), 47 (1951)

(8) Gray P.G., "The Use of Heating Appliances and the Expenditure on Fuel by Urban Households Living in Dwellings of Medium and Low Rateable Value". Central Office of Information, London (May, 1954)
Gray P.G., "Domestic Heating", Central Office of Information, London (1958)
"A Study of Space and Water Heating in Local Authority Flats, 1956-1959". National Building Studies, Research Paper No. 34, Her Majesty's Stationery Office, London.

(9) See over.

(9) Methods have been devised of accurately measuring smoke emissions from the appliances. (10)

37. Standards for domestic solid fuel appliances are prescribed in British Standard Specifications (11). In general these appliances will burn either coal or solid smokeless fuels. In addition, automatic gravity feed boilers are available which operate with a range of graded solid smokeless fuels. The overall efficiencies of the appliances when burning smokeless fuels range from nearly 50 per cent for the open fire to about 75 per cent for the gravity feed boilers.

38. Appliances which meet the British Standard Specifications may be included in a list of approved domestic solid fuel appliances which is used by local authorities and others in selecting solid fuel appliances for new houses. Similarly, lists of tested and approved domestic gas appliances and of recommended domestic electrical appliances have also been compiled. Advisory services for local authorities, architects and householders on the domestic use of fuels and on the appliances in which to burn them are provided by the Coal Utilisation Council, the Solid Smokeless Fuels Federation and the fuel and power industries.

39. The standard of structural insulation in new dwellings is controlled by byelaws. In existing houses, an economic method of reducing heat losses at small cost is to improve the insulation of the ceiling of the upper rooms. Information on methods of insulating existing houses is made readily available to occupiers.

40. The Clean Air Act, 1956, is having an important effect on the domestic use of fuel. The Act, among other things, enables local authorities to promote smoke control areas in which smoke from chimneys of any kind is prohibited. By mid-1962, 567 smoke control orders covering 626,000 premises were in operation, and a further 498 orders covering 653,000 premises had been confirmed or submitted for confirmation. Most of the householders in smoke control areas who were previously using coal changed to solid smokeless fuel. At the same time there has been an increase in the numbers of electrical and gas appliances in smoke control areas.

Transport

41. The efficiency of the use of fuel and energy in transporting goods and passengers is a subject which has received much attention since the

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(9) Davison, M. Kimber, D.E. and Tulett R.E.J., "Field Tests to Evaluate the Performance of Free-Standing Convector Fires with Restricted Throats", J.Inst.Fuel, 28, (170), 123 (1955)

(10) Dickinson R, and Kimber D.E., "An Electro-Precipitator for the Assessment of Domestic Smoke" and "Some Measurements of the Smoke Emission from Domestic Appliances", National Society for Clean Air, International Clean Air Conference (1959) London, Papers 54 & 55

(11) British Standards 758 Parts 1 and 11: 779; 1252; 2845, Parts 1 & 11; 3128; 3376; 3378. British Standards Institution, London

last war. The comparisons made between the various prime movers are often based on those factors, particularly of costs, which can be fairly readily assessed and may ignore many others which are not so obvious, e.g. paid for out of a social service. Particularly is this the case in old established countries where to an appreciable extent the methods of transport in use are traditional. Newly developing countries may be in a better position to achieve systems of transport which are efficient from all aspects and most suited to their needs.

42. In the U.K. probably the most significant change in the whole field of transport, except in the air, is the way in which the diesel engine has tended to oust other forms of prime mover. This is because of the higher efficiency of the diesel in terms of energy yielded to fuel consumed and because in general a wide range of liquid fuels can be utilised by appropriate design of the diesel engine.

Road

43. Electrically operated tramways and trolley buses, once very popular in British cities, have now almost completely disappeared. Whilst efficient in energy consumption and utilising indigenous fuel and capable of moving large numbers of people quickly, they have given place to diesel engined buses on grounds of the high capital cost of installing the necessary electrical wire and cable systems and the inflexibility in routes which results from these systems and also because under the heavy traffic conditions found in many cities, they lacked mobility. Public passenger road transport[12] and heavy goods vehicles are now almost wholly diesel engined. Despite the use of higher compression ratios the petrol engine (efficiency 20-28 per cent at most) is not capable of competing with the road diesel (efficiency 30-42 per cent) in running costs and only maintains its hold in the private car field on grounds of quietness, smoothness and wider speed range. Light goods vehicles and taxis are becoming increasingly diesel engined because of their outstanding fuel economy.

Rail

44. The diesel engine and, when appropriate, electrification, are rapidly ousting steam on British railways. Here the efficiency of the diesel is not so high as in road work because of the losses in the electrical means usually adopted to transmit the drive to the wheels, which results in an efficiency of some 28 per cent. This compares with 7-8 per cent for the steam locomotive at best and which is considerably lower when used for shunting. As a result of this and other factors,

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(12) Wilford A.T., "Fuel Economics of Public Road Transport." J.Inst.Pet., 12, 227, (1958)

of which an important one is the extension of electrification, the coal consumed by the railways has fallen from 12.2 million tons in 1956, when the use of diesels commenced, to 7.7 million in 1961, whilst diesel oil consumption has risen only from about 19,000 tons to 430,000 tons, during which period there has been little change in train-miles. It remains to be seen how the life of diesel locomotives compares with those of steam. Electrification schemes which should show an overall efficiency of about 18 per cent, based on coal delivered to the power station, are being installed on those lines where traffic density warrants the high capital cost.[13] [14] These schemes are based on the use of power from the normal electricity supply at 50 cycles and 25 kV. Power for electrification does not yet represent a substantial proportion of the fuel and power bill of the railways.

Canal

45. Many of the canals of the U.K. were in existence before the railways but a number have now been abandoned. The diesel-engined barge is the normal unit to-day, but restricted width in locks prohibits, over much of the system, the use of barges greater than 7 feet beam and hence limits their carrying capacity to 20-25 tons. Diesel oil now represents the bulk of the fuel used in water transport.

Sea

46. At sea the diesel engine is likewise making considerable progress. Whilst for oil fired turbine ships the propelling machinery is considerably lighter than the diesel engine of corresponding power, the latter because of its high efficiency at sea, which may be 40 per cent, is, when considered together with its fuel, appreciably lighter. Whilst the diesel engine is now becoming available in much higher powers there are for marine work other considerations which may still favour steam. Gas turbine propulsion has made little headway. Designs are being considered in the U.K. for nuclear powered ships.

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(13) Wheatcroft E.L.B., and Barton H.H.C., "The Potentialities of Railway Electrification at the Standard Frequency". Inst.Elec. Eng. 103, 411, (1956)

(14) "British Railways Electrification Conference", Engineer, 210, 587 and 621, (1960)

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Agenda Item : A. 3. 2. 2

Afghanistan

APPLICATION OF HYDROLOGY IN WATER RESOURCES DEVELOPMENT IN AFGHANISTAN

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APPLICATION OF HYDROLOGY IN WATER RESOURCES DEVELOPMENT IN AFGHANISTAN

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TRADITIONAL PRACTICES IN WATER MEASUREMENT AND DISTRIBUTION:

1. Afghanistan located in the central part of the Asian continent is of mountainous physical nature. The existence of mountain ranges in the northern and central parts and flat areas and desert zones in the south creates a variable nature as far as topography, climate, water and soil resources and other natural characteristics are concerned. The extremes, that are, freezing and snow in majority of the northern region and hot and dry nature of the south compells us to not think of practicing simple methods of hydrological investigations, but various and elaborate methods and procedures have to be applied.

2. Application of modern techniques of hydrology have taken place very recently in Afghanistan, and old regional practices were and to a certain extent are customary, These traditional practices were not carried on in order that the results be used for design of irrigation system, flood control or as basic data for water development planning, but the sole intention for use of these practices was to facilitate in the distribution of water among water users for irrigation. Estimate of quantity of water was made in a rough manner considering the width and depth of water, but there was no means for determining the velocity component of discharge. Also the quantity of water required for operating a water wheel of a flour mill (in general the wheels are made of wood with outer diameter of vanes about one meter, with vertical shaft) called a "mill water" served as an approximate unit of discharge in distribution of water. This amount of discharge is about 1.5 to 2 cubic feet per second. The discharge of canals is approximated in terms of so many 'mill waters' by the parties concerned and is distributed among them. This practice is still very common among the farmers. Construction of masonary or wood structures with a number of openings in the form of rectangular wiers for distribution purposes is also practiced, which is the most effective and satisfactory means of water distribution in many localities among farmers.

3. Only relative quantity of discharge from the water marks on banks of channels

left after floods were observed and compared to historical flood quantities. For the rivers where no data is available, this visual and comparative study is still practiced and use is made of it for the development investigations.

ORGANIZATIONAL ASPECTS OF HYDROLOGICAL SERVICES:

4. In Afghanistan where agriculture is the back bone of the country's economy, for the expansion of agricultural activities and raising its standard, it is a must that effective use of the water resources be considered. In order to meet the requirement for irrigation, power production and domestic needs, it is understood that coordinated efforts with regard to the use of water is needed. Investigations, collection of basic data and appraisal of water resources of the country which are essential to the scientific planning of irrigation, water supply and hydro-electric projects have to be performed in a more effective manner.

5. In Afghanistan the responsibility for water resources investigation is divided among several agencies with none of them exercising the functions of coordination and the establishment of uniform standards. As a result there is a considerable amount of inefficiency and duplication of efforts in the collection and use of basic hydrological data for the water resources development programs.

6. Water as the main resource of the country, it is stressed upon that the responsibility for its management and its operation should not be divided according to use that is irrigation, energy development, water supply and control. Since water resources investigation, management and development is a continuous concern, it needs long range programs based on stable policy and organization.

7. In the field of water development investigation in Afghanistan, having considered the important factors such as, the varying, nature and scope of water requirement, urgency and quantity of water needed for development plans, establishment of water rights and legislation, lack of sufficient number of technical development, lack of conformity and irregular standards of work, lack of complete coordination among various agencies and their effectiveness and result high expenditures, important step is taken towards the centralization of the various agencies into one organization. This organization could best provide coordination, regular direction, stability to water resources investigation programs and planning for development.

8. The functions of this central organization are:

(a) General study of surface and ground water in Afghanistan.

(b) Collection of measurements of surface water by use of modern technical means and presentation of data to national and international interested groups.

(c) Coordination of water construction works

(d) Study of flood control

(e) Study of possibilities of formulation of the Afghan water legislation and water policy.

(f) Completion of the hydrometric network of the country.

(g) Detailed study and exploration of ground water in promising areas.

(h) Presentation of subsurface water data collected to agencies concerned.

(i) Compilation of data for design of water development projects.

(j) Drilling exploration and development wells for ground water.

(k) Preparation of standard specifications for completion of water wells.

(l) Acting as consultant in the utilization of surface and ground water to interested parties.

(m) Study of solid and load transport of water bodies.

(n) Analysis of water

(o) Collection of hydro-meteorological data and analysis.

IRRIGATION - POWER STUDY ON OPERATION OF ARGHANDAB DAM RESERVOIR AND ITS AFFECT ON IRRIGATION SUPPLIES:

9. The Arghandab dam located in Kandahar province completed in 1952 on Arghandab river with its primary function to supplement the low water flow of Arghandab river for irrigation use. Generation of hydro-electic power is also provided to serve the need of the city of Kandahar. The dam as an earthfill embankment, is 50 meters high, crest width of 540 meters, with a storage capacity of 388,000 acre feet. Irrigation water is led through a tunnel in the right abutment controlled by two valves and gates. Outlet for power is also located at tail end of the tunnel.

10. Since no prior stream flow records were available a design flood hydrograph was developed by analitical methods, considering flood records from snow fed streams in other parts of the world having comparable watersheds. From these investigations the spillway capacity was determined to handle a maximum discharge of 225,000 cubic feet per second.

11. A study is made of the maximum combined output for irrigation and power development in the operation of the Arghandab reservoir. The fourteen years data from 1947 to 1961 is used and efficient operation computed month by month and year by year for the entire period. Average monthly inflow, required monthly diversion and average usable diversion as percentage of totals for average year is shown in table (I).

12. The study is based on full irrigation of 105,000 acres (41% vineyard, 26% wheat, 20% orchards, 13% cotton with cover crops, summer and winter legumes and vegetables), using an average irrigation efficiency of 55%, a delivery efficiency of 75%, a return flow usage of 5%. Generation of 9,600 kilowatts for six months and 2,500 to 7,500 kilowatts for the remaining months of the year and in so far as possible a full reservoir at begining of June and a carry over of 120,000 acre feet is also anticipated.

13. Particular attention was given to the fact that the months of June, July and August are the hottest months of the year, accounting for over 40 percent of the total annual evaporation and have no effective rainfall (out of 7.3 inches 5.4 inches of rainfall is effective). Consumptive use is highest. About 60 percent of the inflow to the Arghandab reservoir comes in during three months of March, April and May and the reservoir holds only about 30 percent of the annual runoff. Mean monthly rainfall, mean monthly temperature, wind velocity and measured evaporation from water surface for Kandahar area is shown in Fig. I.

14. In table (2) the usable reservoir release, evaporation losses, the uncontrolled spill and the reservoir release in terms of overall irrigation requirements, for average of fourteen years, average of eleven high water year and average of three low years is shown. This summary indicates that the eleven high years produce 126 percent, the average of all fourteen years produce 114 percent and

the average of three low years produce 70 percent of the overall requirement for irrigation (730,000 acre feet). The uncontrolled spill may be diverted and used for wheat or other crops which are needing water for maturity at that period.

15. The application of this studied and recommended operation required a change in the irrigation practices of the farmers and strict control of water in the irrigation zones. To change the irrigation practices already customary among the farmers takes time and effort. Due to lack of proper diversion and intake structures at the canals 15 to 20 percent of water released for irrigation, during the months of low flow could not be lifted and is wasted. Excessive water was demanded to raise the water level in the river channel to the limit possible for diversion into the canals. Therefore the operation of the storage reservoir exactly in compliance with the studied case was not possible at that stage, but year by year improvements are visualized and the difference between the practiced and recommended operations becomes less.

SOME METHODS AND APPLICATION OF HYDROLOGY:

16. Application of modern techniques in hydrological investigation in Afghanistan has taken place about one and half decades back. At that time, planning of vast water development program in the south emphasized upon the urgency and need of the basic hydrological data of the rivers flowing in the southern part of Afghanistan.

17. In accordance with technical standards design and construction of hydrological investigation station, collection and analysis of hydrological data is being performed. With the hydrological stations in existance (see fig.II) a complete appraisal of water resources of Afghanistan is not possible at present, but the intensification of hydrological network is to be carried on in order to give us a more detail and clear picture of the country's water resources. Stations including automatic water stage recorders, cableways, evaporation pans, rain gauges are installed on major rivers and additional similar installations will be completed on the remaining water courses.

18. Masonary orcorrugated metal pipe shelters for automatic water stage recorders are erected, but due to difficulties in obtaining the large diameter corrugated metal pipe in the country the use of rock masonary structure is best adaptable. Transportation problems and lack of roads to many of the gaging sites also favour the masonary construction of shelters.(see Fig.III)

19. Erection of staff gages outside the shelter is practices on all of the stations where with tape measurement of water level inside shelter, checks the automatic stage recordor readings. Readings of outside staff gage observed regularly by gage readers during the flood period is substituted for the lost records in cases when the inlet of the automatic recorder-shelter is plugged by silt deposits. Similarly during the freezing season when water inside the recorder shelter freezes and the operation of the automatic recorder stops, then by breaking the ice around the outside staff gage direct reading of the water stage is obtained from the staff gage. The existence of excessive draw down, and plugging of inlet of the shelter is normally determined from the existance of a difference between the readings of outside and inside staff gages.

20. Due to safety reasons, accuracy of measurement and complications due to boat drift and application of correction, preference is given to the discharge measurement from cableways than from boats. Direct discharge measurements is made by wading in low water period, but during the high water period cableways are used.

21. Single track cableways are erected close to recorder structures on the major rivers, and construction of double track cableways are underway on some of the central rivers. It is anticipated that the carriage (cable car) on a double track cableway will be more stable against the lateral movement due to wind forces. Of course after a period of experience and comparing the two types of cableways construction as to their operation, effectiveness accuracy of measurement and cost, one of the two types will be selected and applied on the remaining stations to be completed in future. It should be mentioned here that the unbalanced cross river movement of the four wheels of the carriage on the wire rope tracks caused by the existance of a difference in sag in the two tracks, will create difficulties, unless exactly equal sag is applied on the two tracks.

22. Installation of automatic longtime operated water stage recorders is necessary on many of the stations. A number of 90 days automatically operated recorders are also installed, where the regular 30 days duration recorders are used on majority of the stations. Due to remoteness from towns and villages and difficulties with regard to accessibility of the station and snow covered passages during 4 or more months of the year application of block-and-tackle arrangement of pulleys to allow long-time operation of recorders is also considered, where the clock weight of the recorder is manifolded, and time between recorder inspections has increased.

TABLE 1

ARGHANDAB RESERVOIR WATER RELATION FOR AVERAGE CONDITION AT FULL DEVELOPMENT

Monthly percentage of Average year

Months	Average inflow %	Required Diversion %	Average usable Diversion %
October	1.96	3.42	3.25
November	3.25	3.42	2.70
December	4.35	3.42	2.70
January	5.20	3.42	2.70
February	7.62	3.42	3.80
March	20.74	3.42	10.80
April	27.70	14.96	14.85
May	16.82	19.64	15.35
June	5.40	11.80	10.80
July	4.06	16.45	13.00
August	1.70	13.75	13.00
September	1.20	2.88	7.05
Total	100.00	100.00	100.00

TABLE 2

SUMMARY OF IRRIGATION - POWER STUDY ON OPERATION OF ARGHANDAB RESERVOIR

	Inflow Acre feet	Usable Reservoir release Acre feet	Evaporation losses Acre feet	Uncontrolled spill Acre feet	Release in % of overall requirement
14 years average	1039700	835000	37000	165000	114
Average of 11 high water year	1226000	920000	40000	250000	126
Average of 3 low water year	507062	512450	30000	none	70

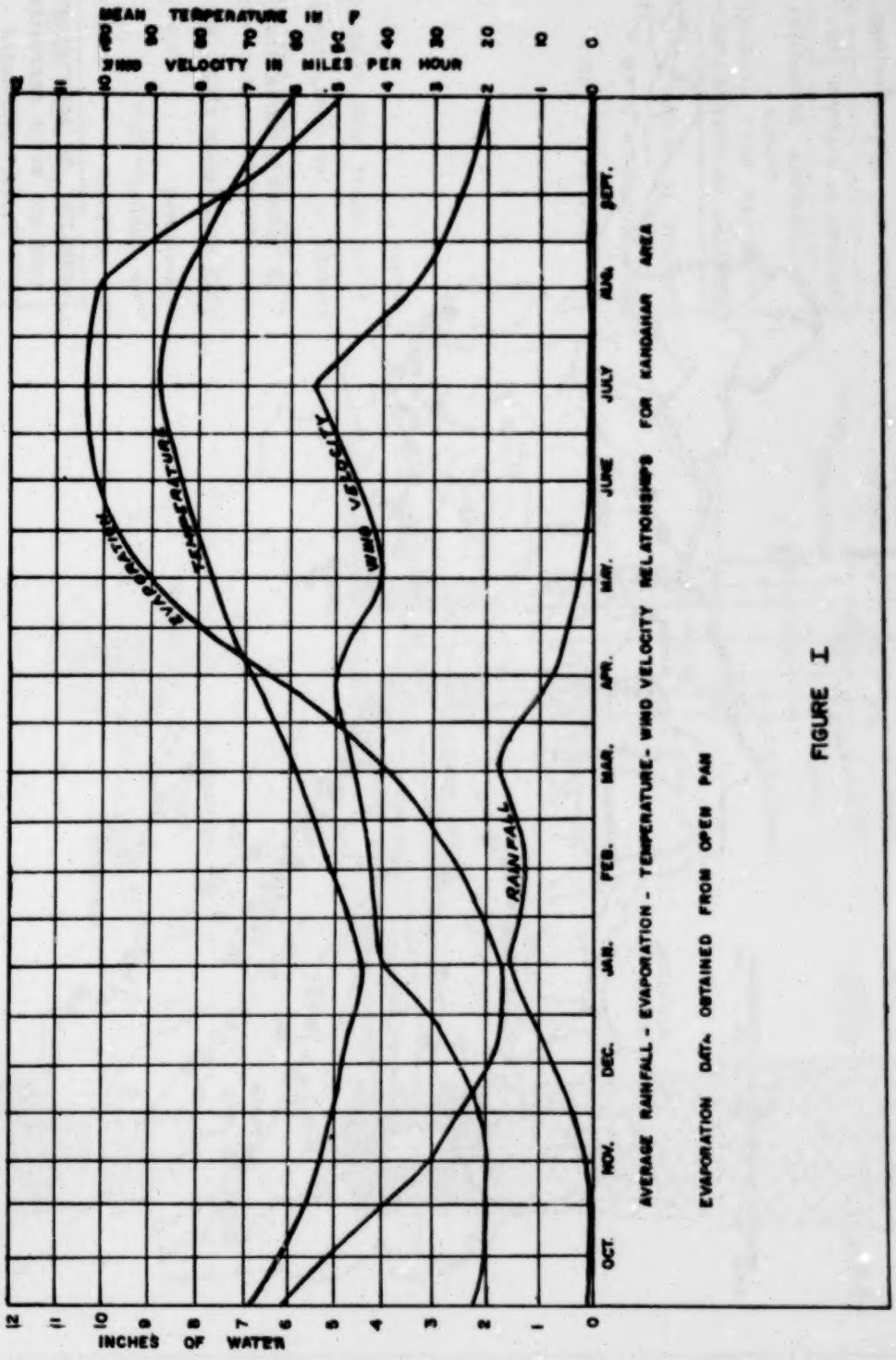

MEAN TEMPERATURE IN F
WIND VELOCITY IN MILES PER HOUR
EVAPORATION
TEMPERATURE
WIND VELOCITY
RAINFALL
OCT.
NOV.
DEC.
JAN.
FEB.
MAR.
APR.
MAY
JUNE
JULY
AUG.
SEPT.
INCHES OF WATER
AVERAGE RAINFALL - EVAPORATION - TEMPERATURE - WIND VELOCITY RELATIONSHIPS FOR KANDAHAR AREA
EVAPORATION DATA OBTAINED FROM OPEN PAN

FIGURE I

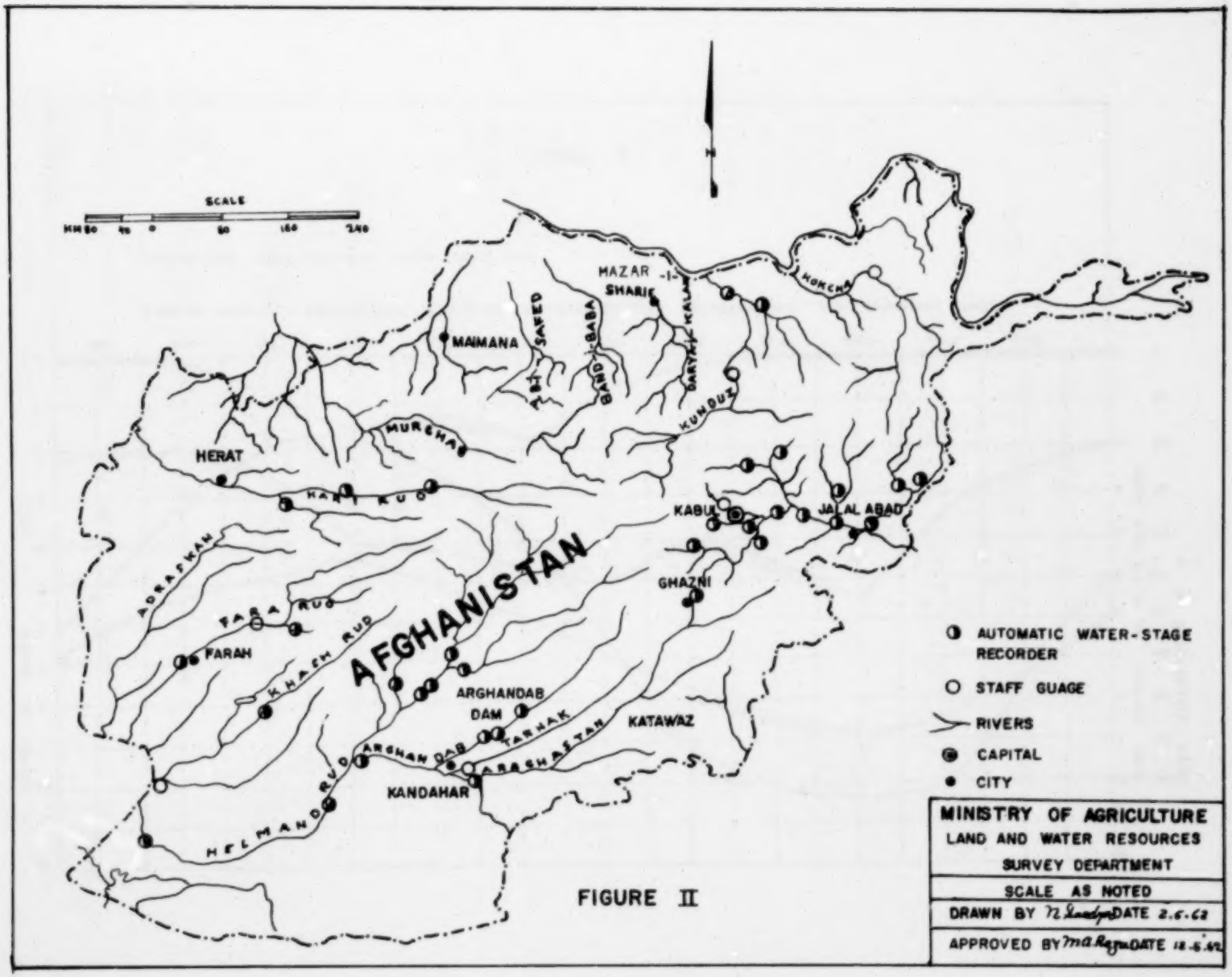
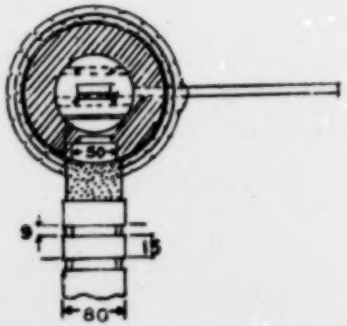
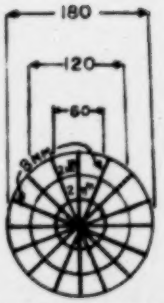

SCALE
KM 50 25 0 50 100 200
N
MAZAR -I- SHARIF
MAIMANA
TEL SAFED
BAND-I-BABA
DARYA-I-KALAN
KUNDUZ
HORCHA
HERAT
MURGHAB
HARI RUD
KABUL
JALALABAD
GHAZNI
AFGHANISTAN
ADRASKAN
FARA RUD
FARAH
KHASH RUD
ARGHANDAB DAM
TARNAK
KATAWAZ
ARGHANDAB
ARASHASTAN
KANDAHAR
HELMAND RV
AUTOMATIC WATER-STAGE RECORDER
STAFF GUAGE
RIVERS
CAPITAL
CITY
MINISTRY OF AGRICULTURE
LAND AND WATER RESOURCES
SURVEY DEPARTMENT
SCALE AS NOTED
DRAWN BY M. Saadyn DATE 2.6.62
APPROVED BY M.A. Raza DATE 12.6.62

FIGURE II



SECTION B-B



ROOF REINFORCEMENT DETAIL

NOTE :-

CEMENT SAND MIX FOR FOUNDATION AND WALLS 1:3

CONCRETE MIX FOR ROOF, BRIDGE 1:2:4

B.M. ELEVATION 2256.848

ZERO MARK OF STAFF GAGE 2251.712

PLAIN REINFORCING STEEL USED.

GRANITE AND SANDSTONE FOR THE STRUTURE FROM AVIALABLE SOURCES AT THE CONSTRUCTION SITE.

4 in Φ METAL PIPE USED FOR INLET.

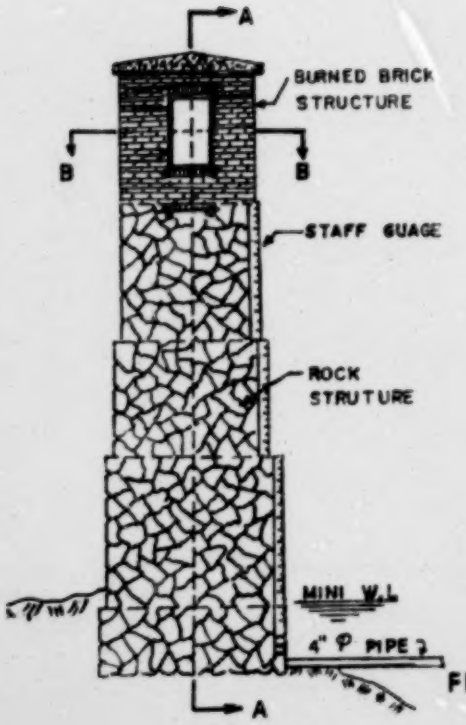
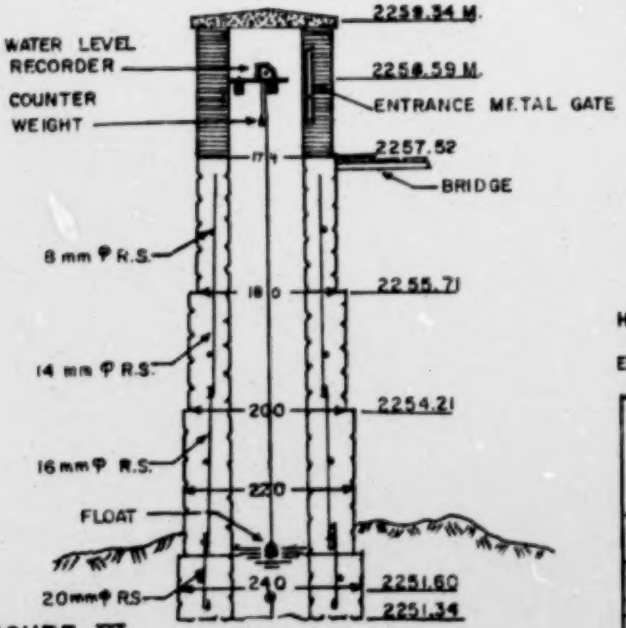


FIGURE III



SECTION A-A

SCALE : 1:80

HORIZ. DIMENSION IN CM.

ELEVATION IN METERS

MINISTRY OF AGRICULTURE-UNSF LAND AND WATER RESOURCES SURVEY HYDROLOGY DEPARTMENT	
DESIGNED BY A. Rashid	NO.
DRAWN BY M. Soodgar	DATE
APPROVED BY M.Q. Raza	DATE 28 OCT 68

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19 Oct.1962
ORIGINAL : ENGLISH

UNITED NATIONS CONFERENCE
ON THE APPLICATION OF SCIENCE AND TECHNOLOGY
FOR THE BENEFIT OF THE LESS DEVELOPED AREAS

Agenda Item: A.4.3.2

Pakistan

PROSPECTS OF NUCLEAR POWER IN PAKISTAN

By Mohammed YUSUF,
Principal Scientific Officer,
Pakistan Atomic Energy Commission,
Karachi, Pakistan

Papers have been contributed to the United Nations Conference on the Application of Science and Technology for the Benefit of the Less Developed Areas as working papers for that Conference. They are published as presented by the contributors, and the contents and the views expressed are those of the contributors. (See notes overleaf.)

NOTES

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2. Papers selected for inclusion in Specialized Sessions will be available at the Conference in only one of the above official languages.

3. Summaries of all papers, as submitted by contributors, will be available at the Conference in the following official languages of the United Nations: English, French, Russian and Spanish.

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No.1668

A.4.3.2.

PROSPECTS OF NUCLEAR POWER IN PAKISTAN

by
Mohammed Yusuf, Principal Scientific Officer,
Pakistan Atomic Energy Commission,
Karachi, Pakistan.

Introduction

1. The standard of living of an average Pakistani is one of lowest in the world. One of the principal aims of the Government of Pakistan is to improve the standard of living of its people, through a series of a long term development plans. The Second Five Year Plan of Pakistan which started in the middle of 1960 is in the process of implementation. One of the short-comings of the Five Year Plans is that the period at disposal is short,-it does not give sufficient time to some of the projects to be completed during the plan period. In fact, the two Five Year Plans of Pakistan could be regarded as one Ten Year Plan. In view of the experiences gained from the Five Year Plans, it is often suggested that the next plan should be over a longer period, possibly of 20 to 25 years. It is in accordance with the principles of such long-term planning that attempts have been made in this paper to foresee the requirments of Pakistan in the field of power generation within the next forty years and also to examine the resources that are available or likely to be available during the period. It is during the analysis of the requirements of the country of the next forty years that nuclear power appears as an alternate and a highly competitive source of power generation compared to other sources presently employed.

2. The power situation obtaining in any country depends on a number of factors which vary from country to country, so that the analysis of the requirements of Pakistan will have to be made in the context of the situation prevailing in Pakistan.

Population of Pakistan in 2000 AD

3. Population of Pakistan in 1961 (1) was 93.8 million, consisting of 50.8 million in East Pakistan and 43.0 million in West Pakistan. The growth of population in West Pakistan during the period from 1951 to 1961 was 27.1% and that in East Pakistan during the same period was 20.9%, the average being 23.7%. During the period from 1901 to 1961 the annual growth of population in West Pakistan was 1.68% compound. It is found that between the period 1931 to 1961 the growth of population in West Pakistan was nearly 2.1% compound per annum. However, it is hoped that as more and more people get educated and as the Government's drive to popularise family planning succeeds, the growth of population in West Pakistan during the next forty years will not be more than 1.68% compound per annum, so that the population of West Pakistan by 2000 AD will be about 83.4 million. In East Pakistan the growth of population between the year 1901 and 1961 was 1.2% compound per annum. It however, does not include the period between 1941 to 1951 when there was practically no increase in population because of famine and war. However, between the period from 1951 to 1961

the growth of population there was about 20.9%. Therefore, for the same reasons as stated above for West Pakistan, it is hoped that the growth of population in East Pakistan during next forty years will not be more than 1.2% compound per annum, so that by 2000 AD the population in East Pakistan will not be more than 81.3 million.

National Income

4. The national income of Pakistan (2) at constant prices on the basis of average prices of 1950-1953 was $ 4750 millions in 1961, the per capita income per annum being $51. This income of an average Pakistani, however, does not give the true picture of the income of the majority population of the country. The distribution of population according to 1961 census was that in Pakistan 87% of the people were living in rural area, the rest in urban area. The occupation of the people living in rural area is primarily agriculture including fishery, forestry, etc. Table I shows that in 1961 the national income out of agriculture was 55% of the total national income. Therefore, about 87% of the population had income of the order of 55% of the total national income. This gives an annual per capita income to a person living in rural area of only $32.5 and to a person in the urban area of $170 per annum.

5. The Second Five Year Plan envisages an increase in the national income by 24%. After allowing increase in population, this will mean an increase in per capita income of 13%. If one thus estimates an increase of 13% in the per capita income of an average Pakistani during every five years of the next forty years, then by 2000 AD the per capita income will be about $136. But instead of keeping $136 as the per capita income on an average in 2000 AD, it is believed that this should be the per capita income of a person living in the rural area. This should not be very difficult to achieve because percentage of population in the rural by that time will decrease and it will increase in the urban area because of more expansion in the industrial sector. It is found from Table I that national income in the agriculture sector has been giving way to the manufacturing sector as it decreased from 61% in 1950 to 55% in 1961. It is estimated that by 2000 AD about 70% of the population will be living in rural area and 30% in urban area. And instead of having a difference of more than 5 times in the average income of a Pakistani living in rural area and the one living in urban area, it is hoped that this difference will decrease to 2½ times in 2000 AD, so that the average Pakistani living in urban area by that time will have a per capita income of $340. The per capita income of an average Pakistani in 2000 AD will therefore be about $200 compared to the per capita income in 1957 of an average U.S. American of $2350, of a Britisher as $790 and of a Japanese as $200.

6. The per capita consumption of power of a country, as shown by several authors (3)(4), bears a straight-line relationship with the per capita income of the country. It applies to all the developed countries and to most of the developing ones. Table 2 shows that there was an increase of 10 times in the per capita consumption of electricity in Pakistan from 1950 to 1960, but there was no increase in the per capita income. This was because there was very little progress in the largest sector of economy, i.e. agriculture, even though there was about 150% increase in industrial sector. On the whole whatever progress was achieved was eaten away by the increase in population. Therefore, instead of taking the per capita consumption of electricity as a measuring yardstick of the development of the country, we should take per capita income, since this would precisely determine the net benefit that an average Pakistani would derive. If we have

to have an average per capita income in 2000 AD of $200 according to the straight-line relationship, this would mean that an average Pakistani in 2000 AD should have a per capita consumption of electricity of about 1000 kwh. This was the consumption of an average Japanese in 1956. However, Japan's economic sectors are mostly energy-intensive, whereas in the case of Pakistan for a long time to come we could assume that our main sector of economy will be agriculture which is not energy-intensive. Therefore, taking a per capita consumption of electricity of 900 kwh in 2000 AD, the generating capacity that will be required to produce power sufficient to meet the demands of that time will be about 20,000 MW in West Pakistan. And taking a 800 kwh per capita consumption, in East Pakistan the generating capacity that would be required by that time will be about 17,400 MW.

Resources for Power Generation.

7. For geographic reasons, East and West Pakistan have been considered separately as far as their power resources are concerned.

8. East Pakistan

(a) East Pakistan consists of a flat deltaic region of two of the largest rivers of the world with very limited hydro-electric potential. The only major source of hydro-electric power from Karnafuli river of 80 MW has been tapped. The Province does not have any coal mine at present. The presence of good quality coal has been detected at a depth of 9000 feet in district Bogra. The depth of the deposit is such that its exploitation is un-economical at present. Peat has been found to exist in a large area of district Faridpur having a calorific value of 4,500 btu per pound. An attempt was made to burn this peat in boilers for power generation. After several years of research the project has been abandoned. No deposit of oil has been discovered so far. There are limited reserves of gas all having been dedicated to fertilizer or cement factories. The lately discovered deposit of 0.7 million million cft. is also being considered for another fertilizer factory.. Beyond these there are no indigeneous resources for power generation. Coal and furnace oil are imported at present to keep the power stations of East Pakistan going.

(b) It will, therefore, be seen that there are practically no indigeneous resources in East Pakistan to meet the growing demand of power of the next forty years, besides importing more and more coal and oil. We may be able some day to develop the coal mine at Bogra and the peat deposit in Faridpur. Whereas such developments may be possible in future, these deposits could not be regarded as resources as far as present long-term planning is concerned.

9. West Pakistan

(a) The theoretical hydro-electric potential of West Pakistan is estimated to be about 25,000 MW. It does not indicate what part of it will be economically and practically developed, for the reason that most of the potential is confined to inaccessible hilly regions of the North and North-West of the Province. The present known deposits of purified quality gas in West Pakistan are estimated to be 9 million million cft. Coal available in West Pakistan is of poor quality and low calcrific value. It is used mostly in cement and brick-kilns and not in boilers for power generation. Its estimated reserve is about 165 million tons. Oil produced in West Pakistan meets internal requirment by about 15% only. In any case, it is not used for electricity generation.

(b) It may be assumed that 50% of theoretical hydro-electric potential available in West Pakistan will be economically developed. This gives us a total generating capacity of about 12,500 MW. The deposit of gas that we

have at present may appear to be large compared to our present rate of consumption, but it should be mentioned that this is less than a year's consumption of gas in the United States (5) and less than 2 years consumption of coal in the United Kingdom. Our availability of gas should be viewed with respect to our long-term requirements in the following fields:

(i) Fertilizer: The total cropped area in West Pakistan is about 35 million acres and that in East Pakistan is about 26 million acres, the total being 61 million acres. The per acre production of Pakistan is one of the lowest in the world. Per acre production of wheat in Pakistan in 1955 was about 702 pounds against 1968 pounds in Egypt (6) and 1926 pounds in Japan and our per acre production of rice in 1955 was 1192 pounds against 3486 pounds in Egypt and 3889 pounds in Japan. There is no reason why we cannot increase our per acre production by intensification of agriculture to equal the production of Japan or Egypt today in the course of next forty years. Japan uses about 56 kg of fertilizer per acre against 2 kg in Pakistan. Since we have resources to produce fertilizer, we could use the same amount of fertilizer in Pakistan in 2000 AD as much as Japan uses today. One pound of nitrogenous fertilizer is understood to require about 25 cft. of gas. On this basis the total requirement of gas for the fertilizer factories to produce fertilizer for entire Pakistan, which would be established by 2000 AD will be about 5.7 million million cft.

(ii) Steel: 1 million million cft. of gas has been reserved for steel plants from the present known deposits (7). It is estimated that by 2000 AD this requirement will double as more and more steel mills are constructed.

(iii) Other Industries: It is estimated that other industries, such as petro-chemical, cement, textile, ceramic, engineering, and miscellaneous industries, will require by 2000 AD about 6.5 million million cft. of gas as against 2.2 million million cft. estimated to be consumed during the next forty years.

(iv) Therefore, to keep the industries which will be established by about 2000 AD going, the total requirement of gas will be about 14.2 million million cft. It can be safely assumed that about 50% of this will be consumed by the industries prior to 2000 AD, so that a total of 21.3 million million cft. of gas will be required exclusive of the requirement of power generation, whereas our present known deposit of purified quality gas is only 9 million million cft. What more deposits will be discovered during the next forty years is anybody's guess.

(c) Since gas could not be available for power generation the gap of 7500 MW in West Pakistan (difference between 20,000 MW and 12,500 MW) could be met only by importing more coal or oil. But gas is being used these days for power generation. This means that less gas will be available to us in future to meet our requirements in other fields.

10. In 1960 alone, for the whole of Pakistan, we had to import over 1.53 tons of coal and over 2.0 million tons of petroleum products spending over $66 millions in foreign exchange.

Future Trend in Conventional Power Costs.

11. Of necessity we should try to develop as much hydro-electric resources of Pakistan as they are practically and economically possible. There is, however, a limit to which this could be done. Table 3 shows a number of hydro-electric projects of Pakistan which have been completed

or are under construction. The capital cost of the projects per kw varies from $450 to $1280. Even though most of the hydro-electric projects are supposed to be multi-purpose, the returns from sectors other than power are insignificant. Therefore, the economic development of any hydro-electric project is of paramount importance. Nobody would probably start these days a project similar to the Karnafuli with so little return. The cost of production of power from these stations per kWh is not exactly known, but it varies from 10 to 22 mills. In fact the age of cheap electricity in Pakistan, it appears, is gone.

12. The oil price in Pakistan varies from 48 cents in Karachi to about 80 cents in East Pakistan per million btu. The FOB price of this oil in Persion Gulf is, as stated by the oil companies, $1.55 per barrel, which is of the order of 26 cents per million btu. So much difference between the available price of oil in Pakistan and the FOB price is due to poor transportation, poor port and handling facilities plus the taxes levied by the Government on oil.

13. There is a slab rate for the gas price in Pakistan depending on the consumption of the gas,-higher the consumption, lower the cost per unit. Oil and gas in Pakistan are controlled by the same group of companies. The gas price is usually aligned to the oil price prevailing in the country.

14. Table 4 gives the price indices (8) of furnace oil and coal which existed in Pakistan since 1955 and which shows that the prices have been going up. Gas price, however, from one source has been going down due to increase in the gas offtake through the pipe line. This sort of decrease is likely to continue till the pipeline reaches its maximum capacity after which it will increase again as and when more pipelines are constructed. Time and rate by which the price will increase will depend on a number of factors. It is only natural to think that the gas price will ultimately increase in Pakistan in course of time. This is however not likely to happen before 1970. As an example, the coal price in the United States in 1940 was $3.40 per ton. This gradually increased to $6.04 per ton in 1955 (5).

Prospects of Nuclear Power in Pakistan.

15 From what has been described above, it is found that there will be large gaps between the demand and the available source of power generation. To meet this gap either we import more conventional fuels at increasingly high cost or find some alternative source of power which could compete economically with power produced from these conventional sources. It is here we find that nuclear power can successfully compete with power from coal or oil or gas and can supplement in filling the gaps. If we have to import more coal and oil, there is no reason why we should not consider importing uranium, assuming that uranium will not be available in Pakistan, if power from uranium is competitive with power from coal,gas or oil. Against the rising trend in the prices of conventional fuels we know definitely that the cost of nuclear power will be going down in course of time because of improvement in its technology and gaining of experience from the plants which are being built around the world. Nuclear power does not only have the potential for economic competition with conventional power sources, but it also has potential for creating a scientific revolution in a developing country by introducing a new concept in the technological development of the country. Besides helping stabilise the conventional fuel prices, it will also give a stimulus to the scientific research on which

depends the industrial development of a country. In other words, the intangible benefits from a nuclear power programme in a developing country will be no less significant than its tangible benefits.

16. The Pakistan Atomic Energy Commission with the help of several consulting engineering firms, International Atomic Energy Agency as well as national atomic energy missions from West Germany, United Kingdom and Canada have made a number of studies about the economic feasibility of nuclear power in Pakistan. These studies revealed a number of things hitherto unknown in the power situation of the country and definitely would help Pakistan to develop national power programme on a rational and integrated basis.

17. The economics of nuclear power in Pakistan for plants of various sizes considered for a number of places are given in Table 5 with respect to conventional plants fired by gas or oil as the case may be. In East Pakistan the competitive source of nuclear power is oil, because gas is not available there for power generation In West Pakistan the source is gas, because it is at present sufficiently available. Coal is out of consideration because it is very costly and furthermore it is not used for power generation except in some power stations built long before. The economics study shows that nuclear power is competitive in Pakistan even at this stage of development of nuclear power technology even in the capacity range of 50 to 150 MW.

18. In view of the economics and the need for power it is believed that nuclear power will be a strong supplement to the conventional sources of power generation in Pakistan in course of time. In order to have such a technology within the country it is necessary that some beginning is made with a small nuclear power plant of 50 MW capacity so that our people learn the technology and soil their hands. It is difficult to have a big nuclear power programme right away because of our limited capability in trained manpower and of the level of scientific and industrial development of the country being not very high, even though our requirements may be urgent so as to suggest the adoption of such a big programme immediately.

T A B L E 1 - National Income.

(Price Average of 1950-1953) (Million Dollars)

Sector	1950		1955		1961	
	Income	%	Income	%	Income	%
Agriculture	2,200	61	2,450	59	2,630	55
Manufacturing	257	7	413	10	645	13.6
Others	1,163	32	1,307	31	1,475	31.4
Total	3,620	100	4,170	100	4,750	100

T A B L E 2 - Growth of Per Capita Electricity Consumption and per Capita Income Per Annum

	1950	1952	1954	1956	1958	1960
Consumption (Kwh)	2.61	4.53	7.49	11.63	17.24	27.6
Per Capita Income (Dollars)	49	49	50	48.5	50.3	50.

T A B L E 3- Capital Cost of some Hydro-Electric Projects in Pakistan.

Name of Station	Warsak	Gujranwala	Shadiwal	Karnafuli	Mangla
Capacity of Station(MW)	160	12	13.5	80	300
Capital Cost $/kW	450	610	625	1280	1180
Remarks	Completed	Completed	Completed	Completed	Under Construction

T A B L E 4- Change in Fuel Prices in Pakistan (Based on 1955 Prices)

Fuel	1955	1956	1957	1958	1959	1960	1961
Furnace Oil	100.00	121.4	122.6	123.1	107.0	105.8	105.8
Coal	100.00	139.5	191.1	217.9	213.6	160.9	171.9

T A B L E 5 - Comparative Cost Economics of Nuclear Power (9)(10)
(Based on 4 interest, 25 year loans)

Plant Capacity & Location (Plant Factor)	Nuclear Plant		Conventional Plant	
	Capital Cost ($ Millions)	Production Cost (Mills/kWh)	Capital Cost ($ Million)	Production Cost(Mills/kWh)
50 MW Plant in Dacca (80%)	26.5	9.53	16.7 (Oil Fired)	11.94
50 MW Plant in Khulna (80%)	26.5	9.53	16.7 (Oil Fired)	12.32
132 MW Plant in Karachi (85%)	42.2	6.30	29.0 (Gas Fired)	6.30
100 MW Plant in Karachi (80%)	35.6	7.14	24.4 (Gas Fired)	7.00
150 MW Plant in Chiniot (70%)	49.5	7.21	30.8 (Gas Fired)	7.87

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UNITED NATIONS CONFERENCE
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FOR THE BENEFIT OF THE LESS DEVELOPED AREAS

Agenda Item: A.3.4.1

Australia

USE OF PAPER-MAKING EFFLUENT FOR IRRIGATION

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B.E. McDOWELL,
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Papers have been contributed to the United Nations Conference on the Application of Science and Technology for the Benefit of the Less Developed Areas as working papers for that Conference. They are published as presented by the contributors, and the contents and the views expressed are those of the contributors. (See notes overleaf.)

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USE OF PAPER-MAKING EFFLUENT FOR IRRIGATION

By D.W. Beattie and B.E. McDowell
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INTRODUCTION

1. The Burnie Board and Timber Pty. Ltd. established a hard-board mill near Brisbane in 1957 to serve the needs of the building industry in Queensland and other Australian States. Effluent from the mill has a large organic content and the consequent high biological oxygen demand makes impractical its disposal by direct discharge into a nearby stream which is virtually stagnant for most of each year.

2. The biological oxygen demand of the effluent can be rapidly satisfied by spreading it over a relatively large area. It was therefore decided by the Company to use this method of disposal as a general practice and, at the same time, experiment with using some of the effluent to irrigate improved pastures.

QUALITY AND QUANTITY OF EFFLUENT

3. The pH of the effluent averages about 4.5 and it contains about 0.2% suspended solids and 0.6% dissolved solids, derived from the woods used in manufacture. Detailed analyses have not been made but the suspended matter is probably almost entirely fine wood fibres, lignin, and similar material while the dissolved matter would be tannins, wood sugars and the like.

4. The average effluent discharge from the mill is 400,000 to 500,000 gallons daily, delivered at a sensibly constant hourly rate throughout the day and night. A substantial part of the effluent is spread over scrub covered land near the mill and the balance is used to irrigate pastures on other mill land.

REMOVAL OF SUSPENDED MATTER

5. No special provisions are made for removing suspended matter from the effluent. However, because of the prime importance of ensuring that no effluent flows into the adjoining stream, irrigation is confined to daylight hours only and discharge during the night is stored until the following day in two earth tanks of 5 million gallons capacity. During this detention period, a considerable portion of the suspended matter settles out and some also settles in the ditches when irrigating.

AREA IRRIGATED AND METHOD OF IRRIGATION

6. Some 110 acres has been put under improved pastures and irrigated with the effluent. The surface slope on the irrigated area varies between one and seven per cent. and contour ditch irrigation was selected as being most suited to the ground conditions. Ditches, six to eight feet wide and one foot deep, have been constructed on a gradient of 0.13% with spoil from the ditch placed on the downhill side to form a low embankment. The ditches are spaced at five feet vertical intervals and intermediate spreader furrows have been provided at vertical intervals of one foot to assist in evenly spreading the effluent.

7. Outlets from the main ditches are provided every 40 feet or so. These outlets comprise a 6 in x 4 in box fabricated from four pieces of 6 in x 1 in timber with the end slotted to take a piece of galvanized iron which acts as a stop.

TYPES OF PASTURE GROWN

8. The irrigated area was originally sown with paspalum, irrigation white and Ladino clovers, H1 ryegrass, phalaris and Priebe prairie grass. Only the paspalum and clovers have survived for the full period, the paspalum predominating. Oversowing with the other species has not been attempted to date.

9. No significant response was obtained from fertilizer trials and fertilizing has not been adopted as a general practice

EFFECTS OF EFFLUENT ON SOIL AND PASTURES

10. To the present time, no deterioration of soil or pastures has become apparent, but it is too early to draw firm conclusions as to what will be the long term results. Some of the suspended matter in the effluent has found its way on to the pasture area where it tends to form a "skin" on the surface of the ground, reducing the rate of infiltration. This problem is overcome by annual chisel ploughing of the area.

11. The pastures are performing reasonably well and provide sufficient feed to fatten one beast per acre on an all year round basis. At times of flush growth, a greater number can be carried.

GENERAL COMMENTS AND CONCLUSIONS

12. Use of the paper-making effluent for irrigation has been quite successful to date, both as a means of disposing of the effluent and as a source of revenue. It is stressed, however, that the former requirement is the important one in this particular case. There is no doubt that the area of irrigated pastures could be increased but the Company feels the limited experience to date indicates it is preferable, for its purposes, to continue spreading most of the effluent on the scrub lands rather than extend the irrigated area.

13. Some additional costs in management have been introduced because of the properties of the effluent but these have not been such as to significantly limit or reduce the economic potential of the area.

14. It appears there is some scope for the use of paper-making effluent in irrigating pastures but to achieve the best results, distribution of the effluent to share-farmers on mill land or to private landholders would appear to be necessary, as the manufacturer would not usually be directly interested in livestock production beyond that needed to reduce the overall cost of effluent disposal.

ACKNOWLEDGEMENT

The ready assistance of the management and staff of the Burnie Board and Timber Pty. Ltd. in preparing this information is acknowledged.

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Agenda Item: A. 4. 3. 1

Economic Commission for Europe

USE OF GAS TURBINE PLANTS FOR ELECTRIC POWER PRODUCTION IN LESS-DEVELOPED COUNTRIES

By The Energy Division of the Economic Commission for Europe

Papers have been contributed to the United Nations Conference on the Application of Science and Technology for the Benefit of the Less Developed Areas as working papers for that Conference. They are published as presented by the contributors, and the contents and the views expressed are those of the contributors. (See notes overleaf.)

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USE OF GAS TURBINE PLANTS FOR ELECTRIC POWER PRODUCTION IN LESS-DEVELOPED COUNTRIES

by

The Energy Division of the Economic Commission for Europe

I. General description

1. Gas turbines are a comparatively new type of prime mover but are already in wide use for many different applications. At present gas turbines are being used in many fields of industry and transport: aviation, power plants, locomotives, ocean-going vessels, lorries and cars, metallurgical, chemical and other industries, oil and gas pumping stations and so on. Besides aviation, and special gas turbines with a short-service life (500-1000 hours) all others have a long-service life (10,000-100,000 hours). In some gas turbines with a long-service life more wearing parts (i.e. first stage blades, burners, etc.) are being renewed after 15,000-20,000 working hours.

2. Long-life gas turbines, including those used in power stations, are being produced in Canada, Czechoslovakian Socialist Republic, France, Italy, Japan, the Federal Republic of Germany, Sweden, Switzerland, the United Kingdom, the USSR, and other countries. The unit capacity of the gas turbines ranges from several kW up to 50 MW. The most powerful gas turbines in use at the present time are the 40 MW set installed in the Vastervic power station in Sweden, produced by the Swedish concern STAL, and the 50 MW unit installed in the Kharkov power station in the USSR, produced by Kharkov Turbine Works.

3. There are three types of gas turbine plants: open-cycle; closed-cycle, and those with free piston generator of working median.

In open-cycle gas turbines the working median enters as air and passes through a compressor, a combustion chamber, a turbine and discharges to the atmosphere. In the closed-cycle gas turbine clear air is used as a working median, which is circulated through a closed system. In gas turbine plants with free piston generators the working median is prepared in the free piston cylinders on the diesel principle but expands in the gas turbine.

4. Open-cycle gas turbines are the most developed and widely used. There are: single-shaft gas turbines which are cheap, simple and less economical, and 2-shaft plants with intercooler, regenerator and reheating working gases which are more complicated. The latter are more expensive but more economical.

Pressure of working median in single-shaft open-cycle gas turbines varies from 3 to 6 atm, and in 2—shaft plants from 10 to 20 atm. The initial tem-

perature of working median in single-shaft open-cycle gas turbine varies from 650 C to 800 C. Efficiency of single-shaft open-cycle gas turbines ranges from 15-20 per cent without regenerator, and from 20-25 per cent with regenerator. For 2-shaft arrangements with inter-color, regenerator and reheating working gases, the efficiency rises and is in the range of from 26 - 32 per cent.

5. Closed-cycle gas turbine plants are comparatively more complicated than open- cycle units. The pressure here is usually 40-60 atm. and back pressure 4-6 atm. The initial temperature of the working median is about 700°C. Efficiency of closed-- cycle gas turbine plants is at a level of 30-32 per cent. Capital investment in such plants is, however, higher than in corresponding open-cycle plants.

6. In gas turbine plants with free piston generators the working median before entering the gas turbine has a comparatively low pressure and temperature is at 4-6 atm. and 420-450°C. It is possible before entering gases to turbine to heat them in the combustion chamber up to 650°C and higher. The efficiency of free piston gas turbine plants is fairly high - 32-34 per cent, but their unit capacity is limited. In existing power plants the largest unit of this type has a capacity of 6 MW.

7. Gas turbine plants for power can use different kinds of fuel: liquid fuel (distilled fuel and heavy bunker oil), natural gas, casing head gases, blast furnace gas and additionally, closed-cycle gas turbine plants can use pulverized coal. The use of natural gas and distilled liquid fuel does not cause any difficulties in the operation of the plant. The use of heavy bunker oils causes some obstacles in servicing, the worst being the deposits of sodium and calcium salts on the turbine blades. A second problem occurs when the heavy fuel contains vanadium, which causes so-called vanadium corrosion of turbine blades at temperatures higher than 650°C. To eliminate these difficulties, the heavy fuel can be specially treated before being used in the gas turbines. A mixture of distilled and heavy oil can be also used in gas turbine plants.

II. Experiences and tendencies in the use of Gas Turbines.

8. At the present time there is a wide experience in the use of gas turbine plants for the production of electricity and also for other purposes. Tables 1 and 2 give some data for selected gas turbine plants used for the production of electric power including their main characteristics. In service gas turbines work to their fullability and have a wide manoevering power.

9. For the past few years there has been a visible tendency in the use of gas turbines for the covering of peak loads. At the same time there is also the tendency to introduce fully automatic plants on which the starting, running and shutting-down is done automatically. This also means that the plant can be operated by remote control without an operator on the site. The plant can be put into operation in a very short time - for some plants it takes 2 minutes only including the taking of load.

10. The second tendence in the use of gas turbines for power is combining production of electricity and heat for heating and other purposes. In this case the efficiency of the plant increases up to 70 per cent.

11. The third tendence in the use of gas turbine plants for power is the use of them combined with steam power plants in so-called steam-gas cycle. This combined cycle increases the efficiency of the plant as a whole by 4 - 8 per cent which brings the efficiency of the combined gas-steam plant up to 40 per cent and higher.

Besides the above three points gas turbine plants are being used as mobile electric power plants, as explained in Section III.

III. Mobile gas turbine plants.

12. Besides stationary gas turbine plants, there are in use, in several cases, mobile gas turbine plants. The use of these mobile gas turbine plants has increased somewhat during the last few years. The mobile plants are mounted on railway trucks or on the chassis of lorries, and sometimes, on special skis when they can be moved by tractor or other transport facilities in the areas where there are no railway, highway or road.

13. Mobile gas turbine plants can be very useful to countries just beginning to develop industrially. In these countries, as a rule, there are not many facilities for deliveries/electricity to isolated areas where industrial plants are being built. When, however, these industrial sites are completed and they have created their own source of electricity the mobile plant can be moved to other isolated areas just starting to develop.

14. At present mobile gas turbine plants are being produced by many turbo producing firms :

Brown Boveri	Capacity of	6.500 kW and 14,500 kW
Bristol Siddley	" "	3,000 kW
Fiat	" "	6,400 kW
General Electric	" "	11,000 kW
Ruston Hornsby	" "	300 and 930 kW
Blackburn Houchin	" "	200 kW
Clark Bros.	" "	5,000 kW

Mobile gas turbine plants are being produced also in the Czechoslovakian Socialist Republic, Soviet Union and different firms in other countries.

IV. Choice of gas turbine plants

15. Before finally choosing gas turbine plants for power one must carefully study both technically and economically all the possibilities and advantages offered by the different types of plants.

16. For the purpose of covering peak loads at a nominal capacity of 10-15 MW and with a considerably short running time (up to 500 hrs. per year), one should choose the most simplest type of plant, i.e. 1-shaft unit without intercooler, regenerator and reheat combustion chamber. If available, natural gas would be the best type of fuel for all types of gas turbine plants used for power. In the above case, if no natural gas is available distilled liquid fuel should be used. As the cost component for fuel for this kind of installation is comparatively small the difference in price between distilled and heavy liquid fuel does not cover all obstacles caused by using heavy fuel. A more complicated, but more economical, plant can be chosen for the covering of peak loads, working up to 3,000 hours per year, i.e. 2-shaft, with intercooler, reheater, and in some cases regenerator. After natural gas one can use heavy fuel oil, bearing in mind that in this case, the fuel component in the cost of electricity is higher and it would be more economical and reasonable to use a cheaper fuel. Gas turbine plants with free piston generators also can be used successfully for the above purposes.

17. For basic load purposes when the plant works 3,000 - 6,000 hours per year it should be chosen a more complete open-cycle or closed-cycle gas turbine plant. Plants with free-piston generator can also be used. In some cases, gases after free piston generator and before entering turbine can be additionally heated in the combustion chamber. Heavy fuel can be used as a fuel if gas is not available.

When choosing gas turbine plants it would be useful to have a consultation with an unprejudiced expert or organisation.

V. Cost of gas turbine plants for power.

18. There is a wide range in the cost of gas turbine plants per installed kW. This depends on many factors, the main ones being as follows:

(1) Application and life span.

19. It is necessary to distinguish between the two types of plant:

a) - for peak load purposes with a short running time per year (up to 500 hours) with a considerably short life span - 10,000-20,000 hours.

b) - plants for basic load purposes with working time over to 3,000 hours per year and with a life span of up to 100,000 hours.

The first, as was mentioned before, are of simple construction and with a considerably low efficiency (18-25 per cent) and considerably cheaper. The second are more complicated with reheater, regenerator, 2 or 3 stages of compression, 2 stages of expansion, and so on. These are more economical (efficiency over 30 percent), and consequently more expensive. Gas turbine plants for the combined production of electricity and heat are more complicated than for the production of electricity only, and consequently, are more expensive but more economical. They have an efficiency of up to 70 per cent.

(2) Fuel used.

20. The values of auxiliaries in connexion with the preparation and burning of fuel depends on the type of fuel chosen. Very few preliminary equipment is needed where natural gas is used as a fuel when it is being delivered to the gas turbine plant at a pressure higher than in the combustion chamber. Where distillate liquid fuel is used, it needs more preliminary equipment than for gas, but less than for heavy fuel. When heavy fuel is used (bunker oil) it is sometimes necessary to make some preliminary preparation to free it from vanadium or from sodium and calcium salts. Besides this it is sometimes also necessary to have preliminary equipment connected with the cleaning and washing of the turbine blades and heat exchanger surfaces from deposits from the different mineral salts and hard products of the combustion. The type of fuel chosen for burning in the combustion chamber of the gas turbine plant influences the cost of installed capacity including the cost of preliminary equipment connected with the preparation for burning fuel and cleaning and washing of deposits.

(3) Unit capacity

21. If the same type of equipment to the gas turbine plants is being installed the cost of installed kW depends on the unit capacity. As a rule, the cost of kW decreases with increasing unit capacity.

22. Besides the above three main factors influencing the cost of the plants, there are many other factors, for instance, the type of plant, market conjuncture of power equipment, and so on.

23. Costs of gas turbine plants based on facts are given herewith according to data given in periodic technical literature.

COSTS OF GAS TURBINE PLANTS BASED ON FACTS AVAILABLE

	Name of stations	Produced by :	Capacity (kW)	Purpose of the plant	Cost $/kW	Commissionning date
1	Alterbacken (Sweden)	Brown Boveri	1 x 25000	Seasonal work	83	1958
2	Manami (Bahrain)	"	2 x 6000	"	139	1958
3	Egmond (Canada)	"	2 x 25000	Seasonal work	172	1957
4	Santa Rosa (Peru)	"	1 x 1000	Peak load	113	1949
5	El Convento (Venezuela)	"	2 x 20000	"	140	1958
6	Ferrybridge (United Kingdom)	Bristol Siddeley	4 x 17500	"	68.3*	Placed order in 1962
7	West Burton (United Kingdom)	English Electric	4 x 17500	" and reserve	68.3*	Placed order in 1962
8	Rio Pecos (U.S.A.)	"	1 x 5000	Basic load	159	. .
9	Caracas (Venezuela)	General Electric	1 x 21500	"	139	1959
10	Pennsylvania (U.S.A.)	"	1 x 22000	Peak load	100	1962
11	Orlando (U.S.A.)	"	1 x 16500	"	110	. .
12	South Carolina (U.S.A.)	"	4 x 11000	"	100	1961
13	Delaware Power Co. (U.S.A.)	"	1 x 11700	"	101.9	1962
	"	Pratt Witney	1 x 12900	"	101.9	1962
14	Georgia (Canada)	General Electric of Canada	2 x 19750	Basic Load	134	1955
			2 x 18000	"	166	1955

* without cost of building

Data given above on the cost of gas turbine plants per kW installed are far from being complete. Nevertheless, they give some idea about this important question. After gas turbines have reached perfection and the unit capacity increased and become more specialized, so the price per kW installed decreases.

TABLE 1

Characteristics of Gas Turbine Plants used in the Production of Electric Power in Europe and elsewhere

NO.	Country	Plant Location	Manufacturer	Type of plant (a)	Year of initial operation	Unit capacity (MW) and number of units	Fuel used	Principal Characteristics							Characteristics of Main Equipment								
															Turbine			Compressor			Generator		
								Thermal cycle (b)	Initial temperature (°C)	Compression ratio	Number of intercoolers	Regeneration effectiveness (%)	Number of heat stages	Thermal efficiency (%)	Number of cylinders	r.p.m.	Inner efficiency (%)	Number of cylinders	r.p.m.	Adiabatic efficiency (%)	Capacity (kVA)	Voltage (kV)	r.p.m.
1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24
1	AUSTRIA	Donawitz	Brown Boveri	B	1958	1 x 4	Blast Furnace gas	0	750		0	75	1	28.0	1	..	..	1	..	..	..	..	..
2		Neusiedl	Brown Boveri	B	1958	1x13.9	Natural gas	0	620	6	0	0	1	21.7	1	..	..	1	..	..	..	..	..
3		Korneuburg	Brown Boveri	B	1959/60	2x25	Natural gas	0	650	20	1	0	2	26.0	2	..	..	2	..	..	35,000	6.3	3,000
4		Schwechat	Brown Boveri	B	1961	1x6.5	Natural gas) Diesel oil)	0	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..
5	UNITED KINGDOM	Princetown	Bristol Siddeley	P	1959	1 x 3	Diesel oil	0	852	7.3	0	0	1	22.0	1	4,250	..	1	4,250	..	3,200	11	1,000
6		Lynton	Bristol Siddeley	P	1960	1 x 3	" "	0	852	7.3	0	0	1	22.0	1	4,250	..	1	4,250	..	3,200	11	1,000
7		Porlock	Bristol Siddeley	P	1961	1 x 3	" "	0	852	7.3	0	0	1	22.0	1	4,250	..	1	4,250	..	3,200	11	1,000
8		Hams Hall	Bristol Siddeley	P	on order	1x15	" "	0	837	..	0	0	1	24.0	1	3,000	..	1	6,300	..	25,000	11	3,000
9		Ferrybridge	Bristol Siddeley	P	on order	3x17.5	" "	0	..	..	0	0	1	..	1	..	..	1	..	..	..	..	..
10		West Barton	English Electric Rolls Royce	P	on order	3x17.5	" "	0	..	..	0	0	1	..	1	..	..	2	..	..	..	..	..
11	FRANCE	Cherbourg	SIGMA	P	1955	1 x 6	Liquid fuel	FP	450	4.1	0	0	1	35.0	1	..	..	8	..	..	10,000	5.5	..
12		Tours	SIGMA	P	1958	1 x 6	" "	FP	650	5.2	0	0	2	25.7	1	7,500	..	6	..	..	10,000	5.5	3,000
13		St. Dizier	Brown Boveri	P	1956	1 x 6	" "	0	750	4.6	0	0	1	20.3	1	..	..	1	..	..	10,000	..	..
14		Angers	Rateau		1958	1 x 6	" "	0	670	4.1	0	0	1	17.0	1	..	..	1	..	..	10,000	..	..
15		Garchisy	S.F.A.C.		1960	1 x 6	" "	0	700	4.5	0	0	1	17.0	1	..	..	1	..	..	10,000	10.5	..
16	ITALY	Livorno	Brown Boveri	BP	1956	2x25		0	650	16	1	0	0	24.0	2	4,750	..	2	4,750	..	32,000	..	3,000
17		Rome	Brown Boveri	BP	1957	1x25		0	650	16	1	0	0	24.0	2	4,750	..	2	4,750	..	32,000	10	3,000
18		Turin	Brown Boveri	BP	1957	1 x 6		0	730	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..
19		Chivasso (Turin)	Fiat		1961	1x32	Gas, liquid fuel	0	730	16.5	1	0	2	27.1	..	5,740/ 3,000	..	2	5,740/ 3,000	..	..	..	3,000

TABLE I (continued)

1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24
20	Rumania	Bucharest	Brown Boveri	P	1948	1x10	Natural Gas	0	600	12		0	2	21.4	2	4,000							3,000
21	Sweden	Västervik	Ljungstrom	P	1959	1x40	Liquid	0	700	13	1	0	1	26.9	2	(3,750 (3,100	..	2	3,750 3,100	..	..	..	3,000
22		Varberg	Ljungstrom	P	1956	1x10	"	0	730	9.8	0	0	1	25.2	1	(6,350 (5,200	..	1	6,350 5,250	5	15,000	6.3	3,000
23		Ottorbäcken	Brown Boveri	P	1957	1x25	"	0	650	16	2	0	2	24.0	2	4,750	..	2	4,750	..	37,500	10	3,000
24		Oxelösund	Brown Boveri	P	1962	1x25	"	0	650	16	2	0	2	24.0	2	4,750	..	2	4,750	..	37,500	..	3,000
25	Switzerland	Neuchatel	Brown Boveri	P	1939	1x4	Liquid	0	550	4	0	0	1	16.9	1	3,000	88	1	3,000	84.6	..	..	3,000
26		Bosnau	Brown Boveri	BP	1948	1x13	"	0	650	8.8	1	80	2	30.0	2	4,750	..	2	3,000	..	16,000	8	3,000
27		"	" "	BP	1949	1x27	"	0	650	8.1	2	80	2	30.0	2	3,000	..	2	3,000	..	33,000	8	3,000
28		Rheinfelden	Sulzer	BP	1959	2x10	"	0	620	4.3	0	70/00	1	26.5	1	..	90	1	..	88	15,000	8	3,000
29	USSR	Shatsk	Loningrad Metal Works	B	1958/1959	2x12	Underground coal gas	0	650	12	1	80	2	27.0	2	..	88	..	..	89	..	..	3,000
30		"	" " "	EH	1962	1x25	Natural gas	0	700	10	1	80	1	28.4		3,000		1	..	..	30,000	..	3,000
31		"	" " "	EH		1x100	Gas, liquid fuel	0	750	20	3	80	2	36.0	2	..	89	3	..	90	..	..	3,000
32		"	" " "	BP		1x100	" " "	0	750		1	0	1	27.0	2	..	89	2	..	90	..	..	3,000
33		"	" " "	"	1961	1x9	Natural gas	0	750	4.5	0	70	1	25.0	1	4,100	..	1	5,000	..	..	..	..
34		Kharkov	Kharkov Turbine Works	EH	1961	1x50	" "	0	800/770	18	2	75	2	33.5	2	3,600/3,000	..	2	3,600/3,000	..	..	..	3,000
35		Kashira	Escher-Wyss	EH	1960	1x10	Pulverised coal	C	677	4.4	1	91	1	28.5	1	6,634	89	2	6,634	85	15,000	..	3,000
36	Federal Republic of Germany	Bremen-Vahr	Brown Boveri	EH	1960/1961	2x25	Fuel oil	0	630	16	1	75	2	25.2	2	4,500/3,000	..	2	4,500/3,000	..	33,000	10.5	3,000
37		München-Sendling	Siemens-Schuckert	EH	1961	1x22	Gas, fuel oil	0	720	6		80	2	28.0	1	3,000	..	1	3,000	..	..	10.5	3,000
38		Oberhausen	Escher-Wyss, GEH	B,EH	1960	1x12.5	Pulverised coal	C	710	8	2	92	1	29.5	1	6,640	..	2	6,640	..	16,000	..	3,000
39		Rheinhausen	Brown Boveri	B	1959/1960	2x15	Blast furnace gas	0	750	5.1	0	75	1	26.3	1	3,000	..	1	3,000	..	20,000	5.2	3,000
..																							
40		Coburg	Escher-Wyss, GEH	EH	1959	1x6.6	Pulverised coal	C	680	4.0	2		1	29.0	1	..	..	..	..	..	..	..	3,000
41		Duisburg	Brown Boveri	BP	1957	1x5.8	Blast furnace gas	0	750	5.1	0	75	1	27.0	1	4,750	..	1	5,250	..	4,600	5.2	3,000
42		Ravensburg	Escher-Wyss, GEH	EH	1956	1x2.3	Pulverised coal	C	660	4.0	2+1	85	1	26.0	1	12,760	..	2	12,750	..	..		3,000

TABLE I (continued)

1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24
43	Canada	Port Mann	Brown Boveri	PC	1959	4x25	Natural gas, crude oil	C	650	16	1	0	2	24.0	2	4,500	..	2	4,500	..	30,000	13.8	3,600
44		Bare Point (Vancouver)	General Electric	PS	1959/1960	(2x20 (2x18	Fuel oil "	O C	737 737	6.4 6.4	0 0	0 ..	1 1	21.1 28.6	1 1	3,600 3,600	.. ..	1 1	3,600 3,600	.. ..	25,000 25,000	13.8 13.8	3,600 3,600
45		Edmonton (Alberta)	Brown Boveri	PS	1958/1959	2x25	Natural gas	O	650	16	1	0	2	24.0	2	..	..	2	4,750	..	..	..	..
46		Kindersley (Regina)	" "	PC	1958	2x10	" "	O	650	4.6	0	0	1	19.0	..	..	..	..	..	..	..	..	..
47	United States of America	Rutland	General Electric	BP	1952	3x5	Fuel oil	C	816	9	1	0	1	26.4	1	..	..	1	8,300	..	..	..	3,600
48		Orlando	" "	P	1958/..	2x16.2	" "	O	737	6	0	0	1	20.6	1	..	..	1	..	..	..	..	..
49		Philadelphia	Westinghouse	P	1962	1x22	Natural gas diesel oil	O	788	..	..	..	..	..	..	..	..	..	..	..	..	..	..
50	Peru	Lima	Brown Boveri	B	1949	1x10	Fuel oil	O	600	8	..	80	2	28.2	2	..	..	1	6,900	..	..	..	3,600
51	Venezuela		General Electric	PS	1957	1x16.5	Natural gas crude oil	O	788	6	0	0	1	20.6	1	..	..	1	3,600	..	..	..	3,600

Notes: a) B - base load
P - peak load
S - stand-by capacity

EH - electricity and heat
.. - no information available

b) O - open cycle
C - closed cycle
FP - with three-piston generators

Table 2

GAS TURBINE PLANTS FOR POWER ALREADY USED IN LESS DEVELOPED COUNTRIES

No	Country	Location of the plant	Manufacturer	Commissioning time	Capacity kW	Cycle	Initial temperature	Compression Ratio	Regenerating efficiency %	Fuel used	Thermal efficiency %	Purpose of the plant
1	Algeria	Hassi Messaoud	Fiat	1962	2 x 6400	0	788	6	. .	gas, liquid	. .	Production of electricity
2	"	Sahara	"		2 x 6400	0	788	6	. .	" "		"
3	"	Haoudel Hamra	"	1960	1 x 6400	0	788	6	. .	" "		"
4	"	Santa Cruz	Brown Boveri	1957	2 x 12000	0	650	4	0	Bunker oil	19,5	"
5	"	Haoudel Hamra	"	1960	2 x 4700	0	650	.	. .	gas	. .	"
6	"	Bône	Oerlikon	1952	1 x 760	0	600	3,75	0	Bunker oil	15,9	Electricity and steam
7	Argentina	Blanco Encalada	Fiat	1961/1962	2 x 6400	0	788	6	. .	liquid	. .	Production of electricity
8	"	Mobile plant	"	1961/1962	2 x 6400	0	788	6	. .	gas, liquid	. .	"
9	"	Sinco saltos	"	1961	1 x 6400	0	788	6	. .	gas, liquid	. .	"
10	"	Barker	"	1961	2 x 5850	0	788	4	. .	gas, liquid	. .	"
11	"	Lujande	"	1961	2 x 6400	0	788	6	. .	gas, liquid	. .	"
12	"	Pico Truncado	"	1961	2 x 6400	0	788	6	. .	gas, liquid	. .	"
13	"	Atnor	General Electric	1961	1 x 5500	0	. .	. .	. .	. .	. .	"
14	"	Olavarria	Zulzer	1962	1 x 6100	0	. .	. .	. .	liquid, gas	. .	"
15	Bahrain	Manama	Brown Boveri	1958/1961	4 x 6000	0	650	4,6	0	gas	19,0	Oil field
16	Brazil	Nova cap	General Electric	1961	2 x 5300	0	. .	. .	. .	. .	. .	Production of electricity
17	"	. .	Westing-house		4 x 6400	0	788	6	0	. .	. .	"
18	Ecuador	Ankon	Ruston Hornsby	1961	1 x 930	0	727	4	0	gas	15,9	"
19	Egypt	Tura	SEME (France)	1957	1 x 3750	F.P	450	4	0	Bunker oil	34,0	"
20	"	Alexandria	Brown Boveri	1949	1 x 1200	0	593	3	. .	"	21,6	"
21	India	. .	Westing-house	Placed order	3 x 23000	0	788	. .	. .	. .		"
22	Iran	Tembi	Brown Boveri	1955/1956	2 x 4000	0	593	. .	0	gas	16,4	"
23	Lebanon	Beirut	Westing-house	1955	1 x 5000	0	732	5,8	0	kerosine Bunker oil	19,0	"
24	Libya	. .	Ruston Hornsby	1961	3 x 900	0	727	4	. .	. .	. .	"
25	Mexico	Mexico City	Brown Boveri	1957/1958	3 x 6200	0	650	4,7	0	Bunker oil	19,1	Mobile plant
26	"	. .	Westing-house	. .	5 x 6400	0	788	6	. .	. .	. .	Production of electricity
27	"	. .	"	. .	1 x 14000	0	788	6	0	. .	. .	"

Table 2

GAS TURBINE PLANTS FOR POWER ALREADY USED IN LESS DEVELOPED COUNTRIES

NO	Country	Location of the plant	Manufacturer	Commissioning time	Capacity kW	Cycle	Initial Temperature	Compression Ratio	Regenerat. efficiency %	Fuel used	Thermal efficiency %	Purpose of the plant
28	Pakistan	Mulfan	Brown Boveri	1960	1 x 5700	0	. .	..	. .	gas, Diesel oil	. .	Production of electricity
29	"	Huderabad	"	1961	1 x 5700	0	. .	. .	. .	"		"
30	Peru	Santa Rosa	"	1949	1 x 10000	0	593	8	80	Bunker oil	28,2	"
31	"	Chimbot Lima	"	1949	1 x 4000	0	593	4,6	0	"	18,3	"
32	"	Santa Rosa, Lima	"	1961	2 x 10000	0	650	. .	0	"		"
33	Saudi Arabia	Drahran	"	1954/ 1956	3 x 5000	0	650	4,6	0	Gas, bunker oil	17,0	"
34	"	Jeddah	"	1955/ 1956	3 x 6000	0	650	4,6	0	Bunker oil	19,0	"
35	"	Riyadh	"	1958/ 1960	4 x 6000	0	650	4,6	0	Bunker oil	19,0	"
36	Venezuela	Pertigalete	"	1949	2 x 1650	0	593	3,0	0	Bunker oil	20,7	"
37	"	"	"	1953/ 1955	2 x 5000	0	650	4,0	75	Gas, Bunker oil	24,0	"
38	"	Pertigalete	"	1960	1 x 5900	0	650	4		"	. .	"
39	"	ElConvento	"	1958	1 x 20000	0	650	16	0	gas	24,0	"
40	"	. .	Westing-house	1954/ 1959	5 x 5000	0	732	5,8	0	"	18,6	"
41	"	. .	General Electric	1957	1 x 16500	0	788	16	0	gas, kerosine	20,6	"
42	Nigeria	. .	Clark Bros.	1962	2 x 6350	0	732	. .	0	. .	. .	"

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CONFÉRENCE DES NATIONS UNIES
SUR L'APPLICATION DE LA SCIENCE ET DE LA TECHNIQUE
DANS L'INTÉRÊT DES RÉGIONS PEU DÉVELOPPÉES

Point de l'ordre du jour : A. 3. 4. 3

France

LA PLUIE PROVOQUEE
ET LA MODIFICATION ARTIFICIELLE DU TEMPS

Par H. DESSENS,
Directeur de l'Observatoire du Puy-de-Dôme

et J. TIXERONT,
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Ingénieur-conseil de la Société de Développement
des Techniques de Pluie provoquée

Les mémoires rédigés à l'intention de la Conférence des Nations Unies sur l'application de la science et de la technique dans l'intérêt des régions peu développées sont des documents de travail. Ils sont publiés tels qu'ils ont été présentés et les assertions et opinions qu'ils contiennent sont celles de leurs auteurs.

NOTES

1. Les mémoires choisis pour être présentés en séance générale pourront être obtenus à la Conférence dans les langues officielles suivantes des Nations Unies: anglais, espagnol, français et russe.

2. Les mémoires choisis pour être présentés en séance spéciale pourront être obtenus à la Conférence dans l'une seulement de ces langues officielles.

3. Les résumés qui ont été rédigés pour tous les mémoires par les auteurs de ceux-ci pourront être obtenus à la Conférence dans les langues officielles suivantes des Nations Unies: anglais, espagnol, français et russe.

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LA PLUIE PROVOQUEE

ET LA MODIFICATION ARTIFICIELLE DU TEMPS

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RAPPORT de Mr DESSENS

Les recherches sur la modification artificielle du temps se sont développées à partir de 1946, à la suite des remarquables expériences d'ensemencement des nuages réalisées aux Etats-Unis par les physiciens de la General Electric.

I - PROCEDES D'ENSEMENCEMENT

a) Principe

Les procédés d'ensemencement se proposent d'obtenir la formation de gros éléments (gouttes de pluie ou flocons de neige) à partir de la multitude de petites gouttelettes constituant un nuage stable.

L'ensemencement en cristaux de glace d'un nuage surfondu (c'est-à-dire constitué par des gouttelettes liquides à température négative) est basé sur la différence des tensions de vapeur de la glace et de l'eau à une température donnée : de cette différence résulte la croissance des cristaux aux dépens des gouttelettes par l'intermédiaire de la vapeur (T. Bergeron, 1935). Lorsque de gros éléments glacés se sont développés suffisamment, leur vitesse de chute devient appréciable tandis que celle des gouttelettes est négligeable ; il en résulte un processus de capture des gouttelettes par les cristaux et une croissance accélérée de ces derniers. Ce processus est appelé "coalescence" (I. Langmuir, 1947).

Pour déclencher la coalescence, il suffit en principe d'arroser le nuage stable en gouttes d'eau de diamètre nettement supérieur à celui des gouttes de nuage. Comme le nuage contient déjà beaucoup d'eau, on a pensé, au lieu d'introduire ces grosses gouttes, à les condenser sur des particules hygroscopiques telles que des cristaux de chlorure de sodium. Avec 10 kg de sel on peut ainsi obtenir 1.000 kg de grosses gouttes, ce qui constitue une économie de poids à transporter.

b) Réalisation

Deux procédés d'ensemencement en cristaux de glace ont été largement expérimentés : le premier (V. Schaefer, 1946) consiste à soumettre le nuage surfondu à un refroidissement localisé abaissant la température au-dessous de -35°C : il en résulte la naissance d'un grand nombre de cristaux qui se dispersent dans le nuage et l'ensemencent. L'agent réfrigérant le plus utilisé est la neige carbonique qui est généralement transportée dans le nuage à l'aide d'avions. Le propane liquide a également été préconisé (R. Serpolay, 1955) et expérimenté, principalement en France.

Le deuxième procédé (B.Vonnegut, 1947) utilise la propriété présentée par des grains submicroniques d'iodure d'argent de servir de germes pour la formation et la croissance de cristaux de glace. L'avantage de ce procédé provient de ce qu'il est possible de disperser l'iodure sous le nuage, par exemple au niveau du sol, quelle que soit la température à ce niveau : il s'agit alors de procéder à l'émission d'iodure dans un site choisi de façon que les courants aériens transportent les particules dans la région nuageuse où la température est inférieure à -4°C, seuil d'efficacité de ce produit. Actuellement, on sait réaliser des générateurs capables de produire 10^{15} particules efficaces pour 1 g d'iodure vaporisé puis recondensé en minuscules particules.

L'arrosage du nuage en gouttes d'eau exige l'emploi d'avions. Les ensemencements en particules salines (solution pulvérisée ou poudre sèche) sont effectués par avions, fusées, ballons ou à partir du sol (situations à forte convection).

c) Résultats

L'arrosage par gouttes d'eau a initié des précipitations détectables par radar ;mais ni cette technique ni l'ensemencement en particules hygroscopiques n'ont conduit à des résultats ouvrant des perspectives d'ordre pratique.

L'ensemencement des nuages surfondus en cristaux de glace à l'aide de produits frigorigènes (neige carbonique, propane) a donné des résultats très spectaculaires : chutes de neige localisées, dissipation de nuages ou de brouillards. Des opérations en cours (notamment à l'aéroport de Paris-Orly) permettent d'escompter des résultats pratiques dans la dissipation ou l'atténuation des brouillards à température négative.

C'est l'ensemencement par l'iodure d'argent qui a donné lieu aux tentatives les plus nombreuses : ensemencements par avions des nuages d'un secteur donné chaque fois que les nuages étaient susceptibles de dépasser le niveau -4°C (Etats-Unis, Australie) ; ensemencements par un réseau de générateurs au sol polluant de particules d'iodure tout l'air d'une région. Souvent, pour sensibiliser les données statistiques, ces ensemencements étaient soumis à une procédure de tirage au sort permettant des comparaisons entre zone cible et zone témoin, périodes d'essai et périodes témoins. L'évaluation statistique des résultats a donné lieu à des controverses si vives qu'aucune donnée précise certaine ne peut encore être dégagée aujourd'hui. Il est possible et même probable que des augmentations de précipitations de l'ordre de 10 à 20% aient été obtenues par des opérations avec avions (Australie) ou avec générateurs au sol (Ouest des Etats-Unis). Il est probable d'autre part que des opérations d'ensemencement par générateurs au sol en vue de réduire les dégâts occasionnés par la grêle aient abouti à des réductions statistiques de l'ordre de 25% de ces dégâts (France 1951-1962).

d) Propositions

Il convient de surveiller les résultats des opérations de dissipation des brouillards, d'augmentation des précipitations et de suppression de la grêle actuellement poursuivies. Nous devons cependant observer que la plupart de ces tentatives ont lieu dans les régions tempérées.

Or, des recherches poursuivies en Afrique Equatoriale par des physiciens français, ont montré que les régions tropicales convenaient mieux que les régions tempérées à des tentatives d'augmentation des précipitations par générateurs au sol d'iodure d'argent. En effet, les masses d'air tropicales sont mieux définies, plus invariables, plus stagnantes, moins polluées par des produits "glaçogènes" industriels que celles des régions tempérées ; de plus, les pluies y sont d'origine convective locale, et l'effet d'une intervention n'est pas noyé dans les précipitations naturelles liées au passage d'une grande perturbation. Si l'isotherme 0°C est relevé de 1 km par rapport aux régions tempérées, il en est de même de l'isotherme -35°C (seuil provoquant la formation de grandes averses) ; d'autre part, les sommets des nuages convectifs sont eux-mêmes relevés de 5 km par rapport aux régions tempérées, ce qui donne à la phase glace une plus grande importance relative.

En conclusion, nous proposons que des ensemencements par générateurs au sol de particules d'iodure d'argent soient effectués dans les régions tropicales. Les opérations devront être conduites par des spécialistes objectifs et désintéressés, avec un matériel parfaitement contrôlé ; des procédés statistiques simples d'évaluation seront appliqués. Les essais porteront sur les saisons pluvieuses et les bordures des saisons sèches, éventuellement sur les saisons sèches. Quelques études et essais préliminaires montrent que les républiques congolaises, le Cambodge, le Vietnam, la Malaisie, le Brésil, entre autres pays tropicaux, conviendraient pour ces expériences.

II - CONVECTION ARTIFICIELLE

a) Principe

La formation de nuages à pluie ou d'orages sur des incendies a été déjà observée dans l'antiquité (Thucydide, Hérodote) ; l'obtention systématique de pluie à l'aide de grands feux a été préconisée par Espy (1840) et par Rové et Gorêg (1938). Desclers en 1930 a proposé que des centres de surchauffe solaire soient organisés pour créer une convection privilégiée pluvigène. Ses idées ont été reprises et modernisées par un autre français, J. Vaillant, et ont donné lieu à un début d'expérimentation en Afrique équatoriale.

Toutes ces observations et suggestions conduisent à dégager aujourd'hui le principe d'une nouvelle méthode de pluie provoquée et de modification du temps : l'effet le plus important de la radiation

solaire à l'échelle de la planète consiste à évaporer de l'eau, de sorte que le mélange air-vapeur d'eau contient une énorme quantité d'énergie ex-solaire. Cette énergie (environ 600 calories par gramme d'eau) est libérée lorsque la vapeur atteint le point de saturation et se condense. C'est ce qui se produit naturellement dans les nuages, et la libération d'énergie est souvent telle qu'elle provoque la formation d'orages, tornades, cyclones et autres perturbations dévastatrices. Les méthodes de convection artificielle considèrent cette énergie latente comme une forme économiquement récupérable de l'énergie solaire. Pour provoquer la condensation, il suffit de refroidir l'air contenant de la vapeur d'eau, et ce refroidissement est obtenu par détente. La façon la plus économique d'obtenir artificiellement une détente contrôlée consiste à tirer parti de la poussée d'Archimède en ajoutant à cette poussée un petit supplément, sous forme d'énergie thermique, supplément juste suffisant pour détruire l'équilibre de l'air et pour le mettre en mouvement ascendant ; si ce mouvement se prolonge jusqu'au niveau de condensation, la libération de la chaleur latente sert de relai et accélère le mouvement ascendant, par suite augmente l'énergie libérée. Lorsque le nuage formé se développe suffisamment, il produit de la pluie.

b) Réalisation et résultats préliminaires

Des incendies de savanes systématiquement allumés à des moments jugés favorables ont permis d'obtenir des nuages et des pluies qui ne se seraient pas manifestés naturellement (Afrique Equatoriale, 1956.) Après examen de ces premiers résultats, des physiciens belges et français ont décidé d'entreprendre des expériences à l'aide d'un ensemble de 100 brûleurs à fuel, dénommé "météotron", dont la puissance thermique est de l'ordre du million de kilowatts. Par suite des circonstances, les essais qui devaient être effectués sur le territoire du Congo-Léopoldville ont lieu en France. Ils confirment les vues exposées ci-dessus.

c) Propositions

1°) La faiblesse et la régularité des vents et la forte humidité des basses couches atmosphériques font des régions équatoriales un terrain de choix pour les premières tentatives d'exploitation de la convection artificielle. Il conviendrait par exemple, dans une région de savanes à pluviométrie insuffisante, d'augmenter les pluies sur une superficie réduite, de l'ordre du millier d'hectares, de façon à la rendre cultivable. Deux objectifs sont à envisager :
- localiser des averses qui tomberaient naturellement sur des zones incultes ;
- créer des averses qui ne se produiraient pas naturellement sur la région.
Accessoirement, l'expérience servirait de test aux méthodes d'ensemencement, la cheminée d'ascendance étant utilisable pour le transfert du sol aux nuages des particules actives.

Les pays de l'Afrique équatoriale conviendraient particulièrement pour ce type d'expériences.

2°) Dans une deuxième étape, il conviendrait d'envisager une action en marge des régions désertiques. Il serait alors indiqué d'essayer d'abord d'augmenter les pluies sur des foyers pluvigènes naturels au lieu de mettre en compétition un foyer naturel et un foyer artificiel, d'augmenter les occasions d'efficacité du foyer naturel.

Dans les régions tempérées, la seule exploitation de la convection artificielle déjà prévisible consisterait à augmenter les précipitations sur un bassin élevé et équipé pour le stockage de l'eau en simulant les nuages convectifs sur ce bassin.

3°) Il a été enfin suggéré que dans certaines régions, l'évolution de situations météorologiques dépend d'une perturbation minime apparaissant en un point névralgique. Il est donc possible qu'une impulsion thermique provoquant la libération d'une énergie latente beaucoup plus considérable soit capable de déclencher une modification du temps à grande échelle.

4°) Il faut enfin recommander la prise en considération de la création de centres pluvigènes selon Dessaliers et Vaillant où il serait exclusivement fait appel, pour créer l'ascendance, à l'énergie solaire. Ce contrôle du phénomène naturel créateur de nuages et de pluies pourrait être obtenu en recouvrant une superficie d'au moins 100 hectares d'une mince couche de bitume sombre et imperméable, pour augmenter l'échauffement par absorption de radiation et empêcher le refroidissement par évaporation superficielle. Une telle entreprise devrait être tentée dans une région ensoleillée, peu ventée et présentant une couche d'air humide au voisinage du sol ; les régions tropicales sont à recommander une fois de plus.

III - CONCLUSION GENERALE

Depuis 1946, les sensationnelles découvertes de physiciens américains ont provoqué la multiplication des recherches sur la modification du temps par ensemencement des nuages. Des résultats pratiques de ces recherches ont été quelque peu décevants, bien qu'il subsiste des espoirs sérieux, notamment en ce qui concerne l'augmentation des pluies dans les régions tropicales par des ensemencements en iodure d'argent effectués depuis le sol.

La vogue des techniques d'ensemencement ne doit cependant pas étrangler le champ des recherches, ni faire oublier que les causes des pluies naturelles sont plutôt thermiques et dynamiques que microphysiques. L'action thermodynamique sur les nuages, au moyen de la convection provoquée, doit donner lieu à une expérimentation beaucoup plus étendue qu'elle ne l'a été jusqu'ici. Des succès d'importance économique sont probables, au moins dans les régions tropicales.

Rapport de Mr TIXERONT

I°) Le but du présent rapport est d'exposer les travaux d'un groupe d'organismes français, publics et privés travaillant en étroite coopération avec la Météorologie Nationale et composé de l'Electricité de France et du Bureau d'Investissement en Afrique, agissant par l'intermédiaire de la Société de développement des techniques de pluie provoquée.

2°) La complexité des phénomènes en jeu dans les tentatives d'influencer les précipitations et d'en démontrer l'efficacité impose la mise au point et l'utilisation d'un faisceau convergent de méthodes et de moyens de mesure, utilisé isolément chacun de ces moyens, se montre impuissant, tout au moins jusqu'ici, à administrer la preuve de l'efficacité des ensemencements de nuages par des substances pluvigènes

a) Mesure de précipitations et méthodes statistiques de contrôle. Cette question est essentiellement abordée en France par EDF sur son terrain d'expérience de la Truyère dans le Massif Central, les résultats montrent, d'une part, l'importance de la qualité des mesures de précipitations et d'autre part permettant de fixer les limites de l'emploi et de la validité des nombreuses méthodes statistiques de contrôle. Nous citons, en particulier, les contrôles d'ensemencement de nuages actuellement en cours et basés sur la "randomisation" de ces ensemencements, ainsi que la mesure de l'intensité des précipitations par le radar.

b) Recherches de laboratoire sur l'activité des substances pluvigènes et les méthodes et appareils de prélèvements et de comptage des particules.

i) Un premier problème consiste à identifier et à compter au laboratoire les noyaux glaciogènes issus d'un générateur de particules dont le débit est de l'ordre de 10^{13} particules par seconde. Une installation permettant de travailler dans des conditions bien connues et reproductibles a été réalisée à SAINT-NIZIER près de Grenoble (FIG. I). Elle se compose d'un tour de dilution permettant de réaliser en continu des concentrations de l'ordre de 10^{4} particules par litre et d'une chambre de comptage dans laquelle les cristaux de glaces formés viennent s'inclure dans une pellicule de résine synthétique fournissant une "réplique" des cristaux.

ii) On a cherché, ensuite, à relier l'activité des noyaux glaciogènes à leur structure fine observée au microscope électronique. Ceci implique une large mise au point des technique de prélèvements sur grille.

iii) Un troisième objectif atteint est la réalisation d'un compteur automatique de particules à usage industriel, permettant de mesurer dans la nature les concentrations en noyaux artificiels émis au cours des ensemencements de nuages cet appareil (FIG. II) peut être utilisé au sol, sur un ballon ou en avion. Il est basé sur le principe d'une chambre à mélange les cristaux formés sédimentent sur un film photographique. La cadence de mesure est de une par cinq minutes.

iiii) D'autres substances pluvigènes que l'iodure d'argent sont également à l'étude notamment les substances hygroscopiques utilisables dans le cas des nuages à température positive. Ces recherches sont entreprises avec la participation de la Délégation Générale à la Recherche Scientifique et Technique. L'expérimentation est réalisée dans un tunnel à nuage où l'on étudie la stabilité

d'un nuage artificiel, ses caractéristiques granulométriques son état thermodynamique et l'effet de l'introduction des divers agents pluvigènes.

c) Essais dans l'atmosphère en vraie grandeur sur le comportement des particules glaciogènes.

i) Un centre d'essais a été installé à SARDIEU (FIG. II) pour étudier la diffusion des particules et mettre au point des méthodes de prospection de l'atmosphère applicable par la suite à toutes les opérations industrielles d'ensemencement des nuages. L'instrument de travail est le compteur automatique employé simultanément au sol, sur un ballon et en avion. Une station météorologique où l'on exécute, en particulier, des radiosondages sur ballon captif, complète le dispositif. Tous les renseignements météorologiques sont ainsi fichés et servent à l'exploitation des résultats de comptage.

ii) Le comportement des noyaux glaciogènes est également étudié dans certains cas particuliers par E.D.F., notamment au Mont-Ventoux par situation d'ondes stationnaires dans laquelle les nuages rassemblent les conditions d'un laboratoire naturel idéal.

iii) Par la suite, l'expérimentation sera portée dans l'atmosphère à des altitudes plus élevées dans la portion active des nuages. A cet effet, un centre d'essais près de LORIENT, en Bretagne (FIG. III), dans une région où la nébulosité est forte, a été créé pour essayer de résoudre tous ces problèmes. Le but du programme est d'étudier la structure des nuages et les processus naturels de précipitations, ainsi que l'effet des ensemencements par avions Aucun moyen de mesure ne devant être négligé, un avion sera transformé en véritable laboratoire volant, permettant d'accumuler un nombre important de mesures qui seront ensuite dépouillées, interprétées puis fichées et qui comprendront :

a, prises de vues cinématographiques continues du décollage à l'atterrissage,

b, mesure de température et d'humidité de la masse d'air,

c, mesure de la teneur en eau liquide et solide ainsi que du spectre granulométrique des gouttes,

d, mesure de la concentration en noyaux glaciogènes naturels ou artificiels.

Une station de radar météorologique permet, en outre, de contrôler tous ces essais.

d) Opérations expérimentales à grande échelle :

i) Nous avons mentionné l'opération conduite par E.D.F. sur la Truyère. Cette opération sert de support aux études sur les méthodes statistiques de contrôle et dans un proche avenir au contrôle des concentrations en noyaux émis au cours d'une opération de grande envergure.

ii) Une seconde opération du même style, conduite par SODETEP, se déroule actuellement en Algérie. Elle a pour but d'étudier en Afrique, sous d'autres climats, les possibilités de transposer les résultats acquis en France.

3°) Les résultats obtenus tant au cours des opérations sur le terrain, que dans les essais en vraie grandeur de Sardieu, sont, certes, encourageants, mais ils ne sont pas significatifs au sens de la statistique. Cependant, l'intérêt économique d'un accroissement même réduit des précipitations est considérable sur le plan de l'énergie hydraulique et de l'agriculture. A cet égard, l'étude de Mr TRESTOURNEL, Inspecteur Principal de la Section Algérienne de l'Office National Interprofessionnel des Céréales (SAONIC), est suffisamment éloquente : elle montre qu'un faible accroissement de l'ordre de 10 m/m des précipitations en avril et mai se traduit par un accroissement de 10 à 20 % des rendements en céréales. Nous pensons que la mise en oeuvre systématique de moyens et de méthodes rigoureuses de travail permettrait d'y voir plus clair, l'intérêt économique d'un accroissement même réduit des précipitations justifie amplement cet effort.

Fig. I CENTRE DE S[t] NIZIER

Mesure du rendement des générateurs de noyaux glacogènes

Cheminée de dilution

Fig. II CENTRE DE SARDIEU

Mesure des concentrations en noyaux glacogenes

Ballon de 150m³ porteur du compteur automatique et pylone de mesures aerologiques

Fig. III CENTRE DE LORIENT

Etude des précipitations

Aerien du radar météorologique de 3,2 cm

Rapport de M. Tixeront (Annexe)

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Agenda Item: A.3.4.1

Australia

REDUCING EVAPORATION FROM WATER STORAGES BY MEANS OF MONOMOLECULAR FILMS

By R.G. VINES,
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Melbourne, Australia

Papers have been contributed to the United Nations Conference on the Application of Science and Technology for the Benefit of the Less Developed Areas as working papers for that Conference. They are published as presented by the contributors, and the contents and the views expressed are those of the contributors. (See notes overleaf.)

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REDUCING EVAPORATION FROM WATER STORAGES BY MEANS OF MONOMOLECULAR FILMS.

By R.G. Vines, Division of Physical Chemistry,
Commonwealth Scientific and Industrial Research
Organization, Melbourne, Australia.

1. Each year, in inland Australia, countless millions of gallons of valuable water are lost by evaporation. Lack of fresh water is a serious problem in the dry interior, and it is virtually impossible to obtain more by such techniques as rain making, for there are few occasions on which rain-bearing clouds appear. Consequently, if anything is to be done to improve the supply, some means must be found for conserving the water already available.

2. An attack on this conservation problem was begun by the Division of Physical Chemistry of the Commonwealth Scientific and Industrial Research Organization (C.S.I.R.O.) a few years ago when W.W. Mansfield developed a method of reducing evaporation. The basic idea has been known for some time but Mansfield first formulated the many problems to be overcome before a really practical scheme (rather than just a laboratory technique) could be achieved. The process involved spreading an extremely thin chemical film over the water surface: pellets of a solid chemical, cetyl alcohol, were stored in a floating gauze raft moored on the water, and from these the protective layer spontaneously spread out.

3. On small farm dams evaporation losses were sometimes reduced by more than 30%. However, this "raft" process was only partially successful, for a variety of unexpected difficulties arose:- some of the commercial rafts were of poor quality and were easily damaged, ducks often sat on them and pushed them so low in the water that they could not work properly, algae sometimes grew over the raft gauzes and clogged them completely. Many unfortunate things of this nature occurred, so much so that C.S.I.R.O. no longer recommends the process for farm dams. Nevertheless, despite the difficulties mentioned, Mansfield's pioneering work showed clearly that under appropriate conditions cetyl alcohol films could be very effective in reducing evaporation from open water storages.

4. A new method has now been developed for treating large reservoirs $\frac{1}{2}$ sq. mile or more in area. The surface is dusted from a boat with a fine, dry, cetyl alcohol powder, which then spreads rapidly to give effective cover. The treated water is easily recognised for the film produced reduces the waves and ripples, and many striking reflection effects can be observed on a fully covered surface. Cetyl alcohol, is, of course, quite harmless to animals, birds, and even to fish, and the quality of the water is not affected.

5. The film is sensitive to wind and will withstand only light breezes before being blown back. Nevertheless, it is rarely completely lost and traces of cetyl alcohol nearly always remain upon the water surface, even if the winds are strong. When the wind dies, complete cover is often formed again very quickly.

6. In the initial experiments the powder was distributed with an agricultural duster. However, difficulties were experienced in storing and handling the finely divided cetyl alcohol, which is waxy in nature, and this led to the invention of an ingenious grinding machine by Mr. C.S. Robertson of the Broken Hill Water Board, working in collaboration with the C.S.I.R.O. Solid blocks of cetyl alcohol are fed on to a rotating wire brush which revolves at high speed and shreds the material to a fine dust: this is then blown through a delivery tube by a fan, and out on to the water surface. In the early stages of treatment, daily applications are advisable, but as it is possible to cover an area of about 1 sq. mile in roughly an hour, the time involved is not excessive.

7. The method has been tested extensively in the last two years, and it appears to be highly successful in calm weather, when evaporative losses are reduced by about 50%; however, in windy conditions the savings are smaller, the efficiency of the present process falling off quite rapidly with persistent winds in excess of 5 m.p.h. This is because the cetyl alcohol film is broken up and blown bodily across the water surface, together with the excess powder needed for film formation. On large areas of water an appreciable time elapses before a major portion of the film is dissipated in this way, but on small farm dams it happens quite quickly, and thus the process is not recommended for these.

8. The effect of wind is a serious problem and it is hoped that means will ultimately be found for supplementing the addition of cetyl alcohol dust from a series of automatic wind-driven dispensers. Nevertheless, despite its limitation, the present method is still economic, for under favourable conditions the cost of treating a large reservoir is of the order of 1d. per thousand gallons of water saved. Full details of the process have been published.[1,2,3]

9. In an earlier method, developed by Mansfield for treating large reservoirs, a concentrated solution of cetyl alcohol in a volatile solvent was introduced to the water surface from a series of drip-feed dispensers on the banks.[4,5] This proved successful over a short test period, but the technique has certain disadvantages: full details of the results obtained will be published in due course.

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Agenda Item: A.3.2.1

Australia

A STREAM GAUGING AND RAINFALL RECORDER FOR UNATTENDED LONG PERIOD OPERATION

By C.J. SUMNER,
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and Industrial Research Organization,
Melbourne, Australia

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A STREAM GAUGING AND RAINFALL RECORDER FOR UNATTENDED LONG PERIOD OPERATION.

By C.J. Sumner, Division of Meteorological Physics, Commonwealth Scientific and Industrial Research Organization, Melbourne, Australia.

1. A versatile recorder for long period operation in exposed or remote locations has been developed by the Commonwealth Scientific and Industrial Research Organization (C.S.I.R.O.), Australia. The object has been to provide a rugged instrument which is cheap and easy to install and capable of operating unattended for periods up to 12 months on its own power supply.

2. The recorder is housed in a weatherproof case, mounted on a tubular steel post through which pressure pipe and wiring pass to remote sensing elements. The mechanism has been designed so that any mechanical sensing device can be coupled to the recording pens to give records of any two variables such as waterlevel, rainfall, temperature, humidity, evaporation, windspeed etc.

3. The recorder is powered by small dry batteries which operate it for at least 12 months. The recording chart is also of sufficient length to provide a 12 months record. It is marked by pressing a pointed stylus on to the special plastic coated paper; this leaves a black dot so that the record appears as a line of small closely spaced dots. This is an improvement over ink pens which tend to record a trace of varying thickness with humidity change. Also the plastic coated paper does not expand in damp conditions, so ensuring more accurate records. Transcription to punched tape for automatic digital computation has been successfully engineered.

4. The recorder mechanism is controlled by a battery-wound spring clock. Since this unit cannot be expected to keep exact time over long periods, a time check device has been included, consisting of a lens which is arranged to mark the chart by burning a small hole in it at each clear passage of the noon sun.

5. For stream gauging the installation includes a small copper pressure tube, the end of which is covered by a synthetic rubber membrane suitably protected, and mounted directly in the river at minimum waterlevel by securing it to a rock or post. The tube is connected to a pressure sensing element mounted in the recorder, which may be up to 300 feet distant. The pressure element moves with pressure change due to water level variations over the immersed

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Sumner, C.J., Single pen, strip chart recorder for unattended long period operation, J. Sci. Inst., 36, 475-477 (1959).

tube and so moves the stylus arm. The position of the stylus is recorded on the chart by the automatic action of the recorder to give a permanent record of river level.

6. At most stream gauging sites it is necessary to obtain rainfall records. These can be provided by a second pen recording on the same chart. Rain is metered by an 8 in. diameter transmitting raingauge mounted in a suitable position adjacent to the recorder and connected to it by twin electric cable. This gauge transmits an electrical impulse for every one hundredth of an inch of rain falling in the collecting funnel, to energise a relay mounted in the recorder which in turn actuates the recording stylus. The stylus passes fully across the chart for 200 impulses or 2 inches of rainfall. It then returns to the zero position to continue recording subsequent rainfall, wo that the record appears as a series of sloping lines, the angle varying with rainfall rate. Total rainfall is assessed by counting the number of passes of the pen across the chart multiplied by 2 to give inches of rainfall.

7. The recorder has been subjected to extensive field trials in a variety of climates and it is now being commercially manufactured in Melbourne. So far 80 instruments have been supplied to various authorities in a number of countries. They have proved easy to install and maintain and have given trouble-free operation over the past three years.

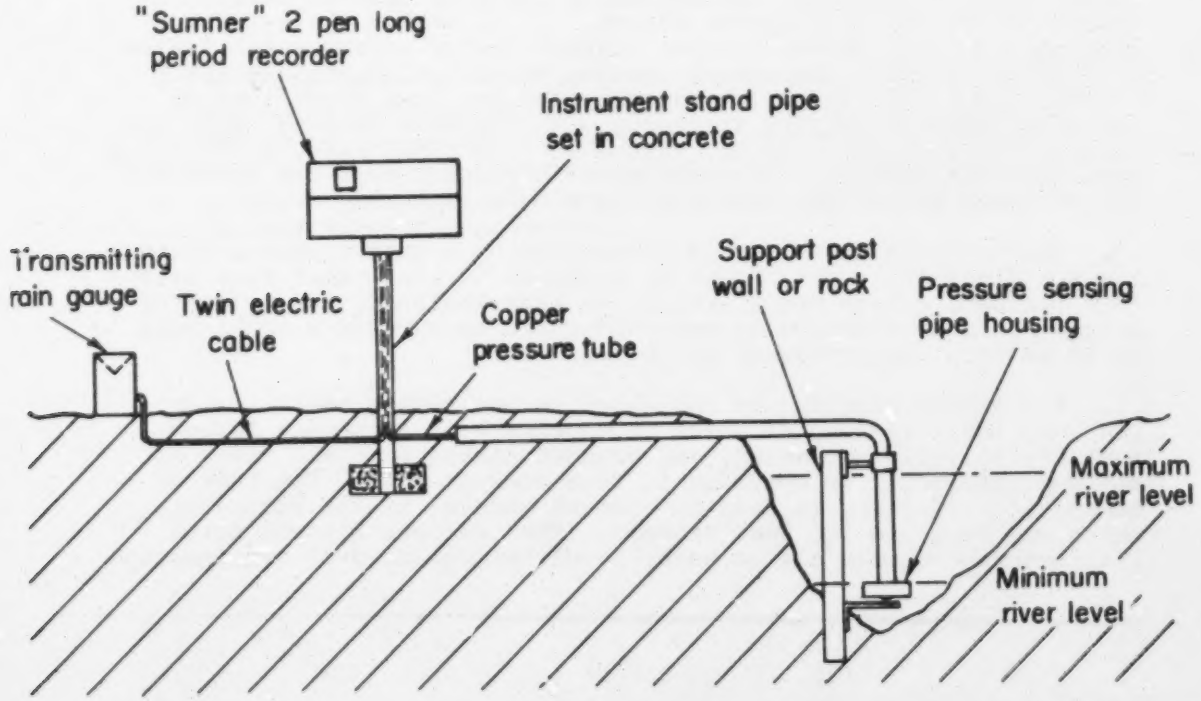
"Sumner" 2 pen long period recorder
Instrument stand pipe set in concrete
Transmitting rain gauge
Twin electric cable
Copper pressure tube
Support post wall or rock
Pressure sensing pipe housing
Maximum river level
Minimum river level

Figure I. Pneumatic water level and rainfall recording installation.

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